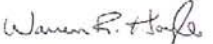


Attachment 8.9

Milne Port Crushing and Screening Geotechnical Recommendations

(118 Pages)

**Baffinland Iron Mines Corporation
Mary River Expansion Project
Geotechnical Recommendations for Stockpile Reclaim Tunnel &
Crushing/Screening Plants**

						
2018-03-29	1	Approved for Use	G Qu	W Hoyle	D Stanger	R Stefan
2018-03-14	0	Approved for Use	G Qu	W Hoyle	D Stanger	R Stefan
Date	Rev.	Status	Prepared By	Checked By	Approved By	Approved By
HATCH						Client

DISCLAIMER

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This report is meant to be read, and sections should not be read or relied upon out of context. While it is believed that the information contained herein is reliable under the conditions and subject to the limitations set forth herein, this Report is based in part on information not within the control of Hatch and Hatch therefore cannot and does not guarantee the accuracy of such information based in whole or in part on information not within the control of Hatch. The comments in it reflect Hatch's professional judgment in light of the information available to it at the time of preparation.

This report contains the expression of the professional opinion of Hatch, based upon information available at the time of preparation. Hatch has conducted this investigation in accordance with the methodology outlined herein. It is important to note that the methods of evaluation employed, while aimed at minimizing the risk of unidentified problems, cannot guarantee their absence. The quality of the information, conclusions and estimates contained herein is consistent with the intended level of accuracy as set out in this report, as well as the circumstances and constraints under which this report was prepared.

Waiver, Release and Indemnification

To: Hatch Ltd. together with its affiliates, the "Consultant"

Re: Geotechnical Recommendations for Stockpile Reclaim Tunnel & Crushing/Screening Plants Report (and together with any subsequent revisions thereof, the "Report") dated March 14, 2018 prepared by the Consultant for Baffinland Iron Mines Corporation (the "Client"), in respect of the design recommendations provided in this document.

The undersigned hereby:

- (a) acknowledges that it wishes to receive a copy of the Report from the Client and that a condition precedent to the provision of the Report to the undersigned is that it sign and deliver to the Consultant this Waiver, Release and Indemnification; and
- (b) irrevocably and unconditionally:
 - (i) waives, releases and disclaims any and all suits, actions, proceedings, claims and any other rights (whether in tort, contract or otherwise and whether past, present or future) that it has or may have against or in relation to the Consultant in respect of or in connection with the Report;
 - (ii) agrees to maintain the Report and the information in the Report strictly confidential and not to provide the Report or any information contained in the Report to any third party without the prior written consent of the Consultant;
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 - (iv) agrees that the waivers, releases, disclaimers and indemnifications set out above will apply even in the case of the fault, negligence or strict liability of the Consultant and will extend to the officers, directors, employees, agents, representatives, subconsultants and related entities of the Consultant.

Dated: [insert current date]

[INSERT NAME OF REPORT RECIPIENT]

By: _____

Name:

Title:

Table of Contents

1. Introduction.....	1
2. Geotechnical Site Information.....	1
2.1 General	1
2.2 Subsurface Soil Interpretation – Silt Layer Thickness	2
3. Climatic Condition	3
4. Stockpile Reclaim Tunnel	3
4.1 Structure	3
4.2 Foundation Design.....	3
4.3 Bearing Capacity.....	6
4.3.1 General	6
4.3.2 Scenario (a) – Two-Layer Foundation	7
4.3.3 Scenario (b1) – Underlying Soil (Friction Only)	7
4.3.4 Scenario (b2) – Underlying Soil (Permafrost Bond Strength Only)	7
4.3.5 Summary	7
4.4 Thermal Analyses	7
4.5 Settlement Analyses	8
4.6 Settlement Results.....	8
4.7 Monitoring/ Maintenance Program.....	10
4.8 Assumptions and Limitations	11
4.9 Recommendations – Stockpile Reclaim Tunnel	12
4.9.1 Construction	12
4.9.2 Excavation.....	12
4.9.3 Backfill.....	13
4.9.4 Drainage.....	13
4.10 Summary and Conclusions.....	14
5. Crushing/Screening Plants.....	14
5.1 Structure	14
5.2 Foundation Configurations.....	16
5.3 Bearing Capacity.....	18
5.4 Thermal Analyses	18
5.5 Settlement Analyses	19
5.6 Settlement Results.....	19
5.6.1 Crushing Plant Settlement	21
5.6.2 Screening Plant Settlement	22
5.7 Monitoring Program	22
5.8 Assumptions and Limitations	22
5.9 Recommendations – Crushing/Screening Plants	22
5.10 Summary and Conclusions.....	24
6. References	25

List of Appendices:

Appendix A 1 Geographical Profile

Appendix A2 Borehole Data

Appendix A3 Thermal Analyses Methodology

Appendix A4 Settlement Analyses Methodology

Appendix B 1 Stockpile Reclaim Tunnel Drawings

Appendix B2 Thermal Analyses – Stockpile Reclaim Tunnel

Appendix B3 Settlement Analyses – Stockpile Reclaim Tunnel

Appendix C 1 Crushing/Screening Plant Drawings

Appendix C2 Thermal Analyses – Crushing/Screening Plant

Appendix C3 Settlement Analyses – Crushing/Screening Plant

1. Introduction

Hatch has been retained by Baffinland Iron Mines Ltd. (BIM) to assist on the design of a Bulk Material Handling (BMH) system at the Milne Inlet Port for the Mary River Expansion Project.

The BMH system consists of a rail car tippler located at the terminus of the mine-to-port railway, a indexer to push the rail car in the tippler, a loadout tunnel connecting with the tippler, a raw ore stockpile with embedded loadout tunnel, crushing and screening plants, and conveyor systems to transfer materials from the tippler through the crushing and screen plants to a longitudinal bucket-wheel stacker/reclaimer.

This memo provides geotechnical recommendations to improve the foundation bearing capacity by using rockfill pads for the footings of (1) the ore stockpile reclaim tunnel and (2) the crushing and screening plants. The settlement caused by the structure loads was assessed and is presented in this memo.

One requirement of the project is to respect the design elevation of the BMH system, excluding any option to raise the footing level. As such, the rockfill pad needs to be placed, at least partially, below the existing ground in a cut/backfill style, with the understanding that cutting into permafrost is not preferred from a technical point of view.

2. Geotechnical Site Information

The geotechnical site investigation plan and borehole profiles are illustrated in the Appendix A1.

2.1 General

Five (5) boreholes (BH 17-M010, BH 16-M010, BH 16-M011, BH 16-M012, and BH 16-M013) were drilled in the area vicinity of the stockpile reclaim tunnel and crusher/screening plants (see Appendix A2 for the borehole reports). In particular, the stockpile tunnel is located between boreholes BH 17-M010 and BH 16-M010. The crusher plant is close to BH 16-M011 and the screening plant is near BH 16-M013.

The subsurface conditions encountered at the site are highlighted as follows:

- The deposit at the site comprise a thin sandy layer overlying a thick silt deposit. Below this is likely a till layer as inferred from the findings in BH 17-M010.
- The sandy layer contains sand, with a varying amount of gravel, trace to some silt and trace cobbles. The thickness of the sandy layer varies from zero to about 3.5 m.
- The silt layer contains dominantly silt, trace to some fine sand, trace gravel, trace organics, with a thickness of 13.7 m at BH 17-M010. This layer likely a deltaic sediment sequence deposit. The frozen silt is general well bonded and contains trace thin ice lenses with a typical ice content from 20% to 40% by weight.

- A 1.4 m thick layer of ground ice was encountered from 1.0 m to 2.4 m depth in BH 16-M010. All other boreholes in this area did not encounter ground ice.
- A till layer (sand till with some silt and some gravel) was encountered in BH 17-M010 at a deep from 13.7 m to 16.7 m underlying the silt deposit. The till layer is well graded and has a relatively low ice content of about 8%.
- Bedrock was not encountered at this area during site investigation (the depth of the boreholes up to 16.7 m).

2.2 Subsurface Soil Interpretation – Silt Layer Thickness

The 13.7 m thickness of the silt layer was confirmed only in BH 17-M010. The other boreholes were all terminated within the silt layer and thus were not able to quantify the silt layer thickness.

As such, it is assumed that the silt layer has a thickness of 14 m as a base-case. A sensitivity check were performed for a thicker silt layer. A 20 m thick silt case was assessed for stockpile tunnel as it is about 40 m to 80 m away from BH 17-M010. A 28 m silt case (double of the 14 m) was evaluated for the crushing/screening plants, which is further away from BH 17-M010 (about 150 m to 400 m).

An interpretation of the sub-surface soil layers for design purposes is provided in Figure 2-1. Further investigation is recommended to confirm/verify the assumption for the thickness of the silt layer.

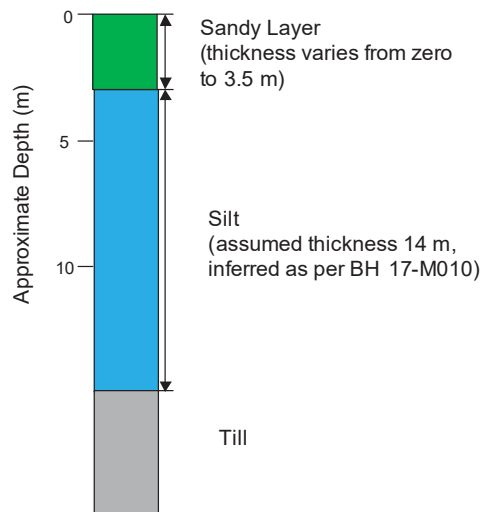


Figure 2-1: Interpreted Subsurface Soil Layers (Base Case)
(For the sites of the stockpile reclaim tunnel and crusher/screening plants)

3. Climatic Condition

The site is in a continuous permafrost zone with a mean annual air temperature of about -15°C , as per the mean monthly air temperature data from Pond Inlet, NU (1981-2010) extracted from the Government of Canada website. Climate information was summarized in Hatch Geotechnical Design Basis document (H353004-00000-229-210-0001, 2018). The global warming effect was taken into account according to the Intergovernmental Panel on Climate Change (IPCC) long term climate change studies. A temperature adjustment was applied considering global warming for the period spanning from 2010 to 2039 (see details in Hatch, 2018).

4. Stockpile Reclaim Tunnel

4.1 Structure

The stockpile over the ore reclaim tunnel is designed to be about 30 m high at the centre, measured from the top to the base of concrete footing and approximate 86 m in diameter for the footprint of the conical ore stockpile, as per the drawings shown in Appendix B1. Figure 4-1 illustrates a cross-section model of the ore stockpile and reclaim tunnel.

The key design inputs / assumptions for the tunnel footings are summarized as below:

- The thin-plate arch tunnel will be founded on a reinforced concrete strip footing with a width up to 6.4 m. The 6.4 m was conservatively used in the bearing capacity assessment and the calculated allowable bearing capacity applies for the smaller size footings. (Note: The drawing of BCSY-A-200 by tkIS shows the footing width of about 5 m and 6.4 m. The drawing of BCSY-K-203 by tkIS shows a footing size of about 3.5 m.)
- The unfactored bearing pressure (allowable bearing pressure) of foundation is 750 kPa (Foundation Loads and Design Criteria, tkIS response to Hatch RFI H353004-CM001-400-465-0045, Oct. 17, 2017, as attached in Appendix B1).

4.2 Foundation Design

The foundation for the tunnel footings consists of two components:

- 3 m thick crusher-run rockfill below the footing base.
- 150 mm thick insulation pad.

Figure 4-2 shows the conceptual configuration for the proposed rockfill foundation.

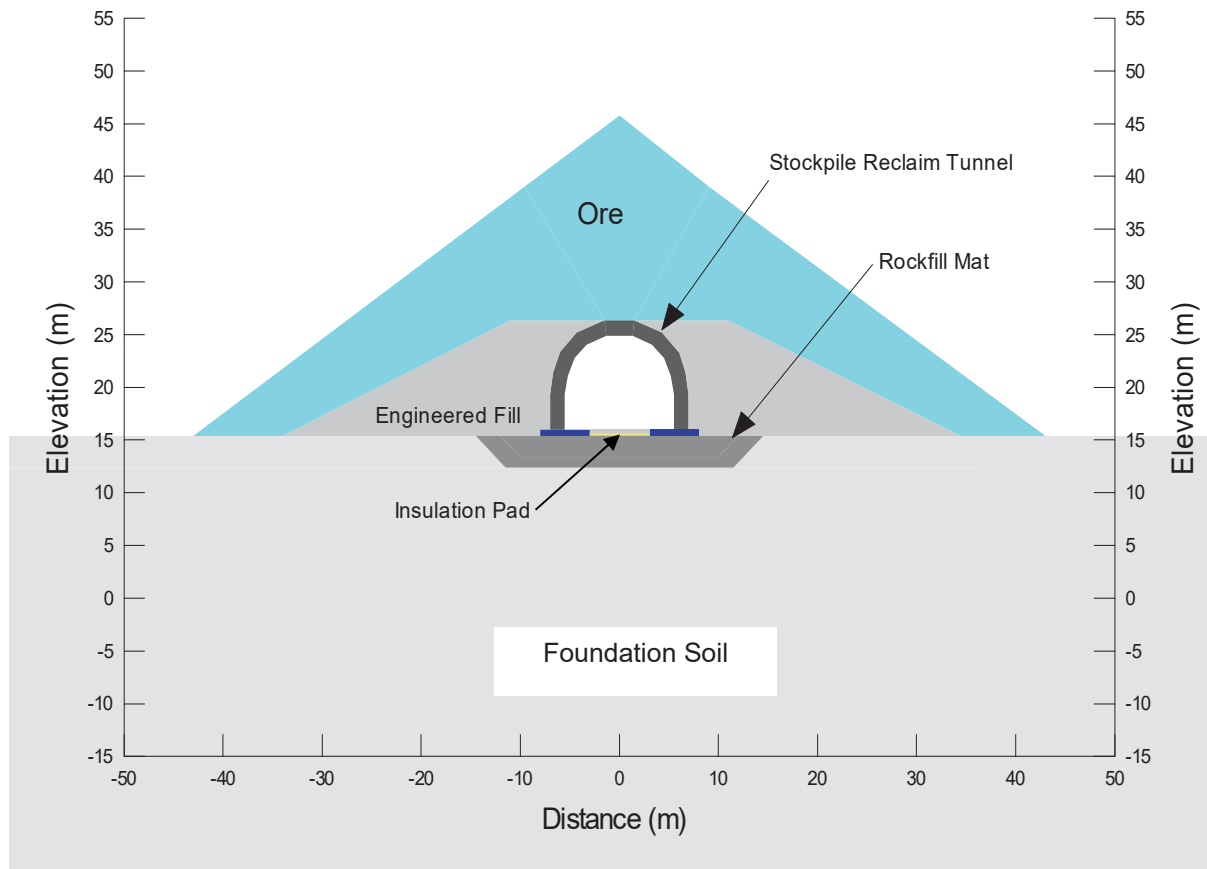
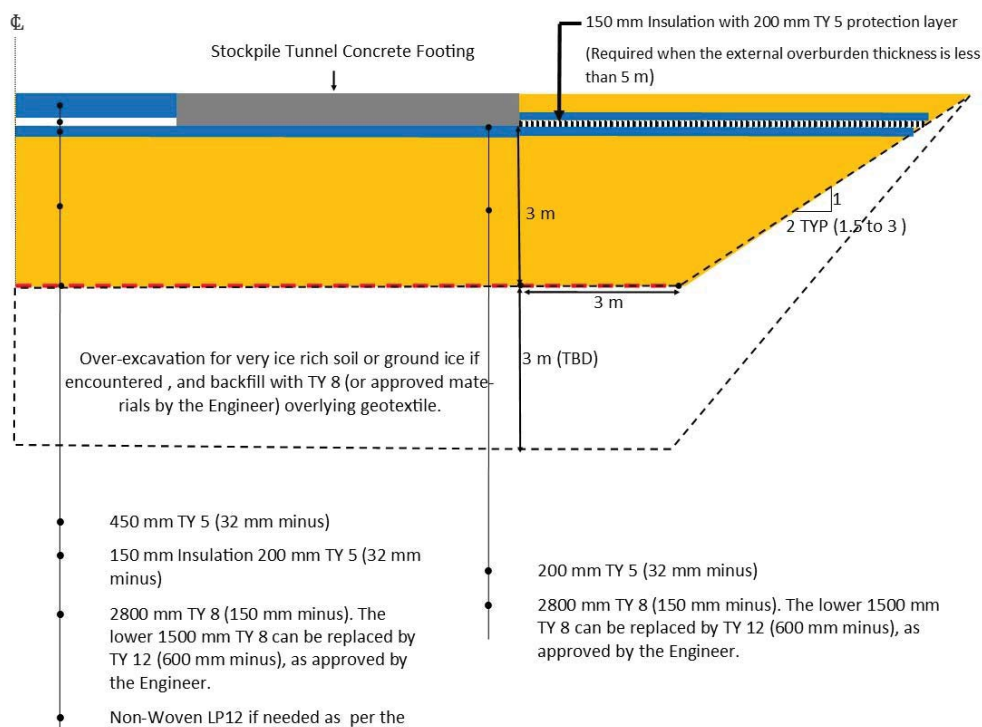


Figure 4-1: Illustration of Stockpile Reclaim Tunnel

Stockpile Reclaim Tunnel Rockfill Pad Design Concept



Legend

	Footing
	TY 5 (32 mm minus)
	TY 8 (150 mm minus)
	TY 9 (9 mm minus), if needed
	Insulation (Styrofoam HL 60)

Notes:

1. The rockfills shall be prepared, placed, and compacted as per Hatch design report / specification.
2. The rockfill pad is designed as per the unfactored footing pressure of 750 kPa. The rockfill pad design should be reviewed and updated for any change of the design loading pressure or the footing size.
3. The tunnel / bulk material handling system should be designed to tolerate the creep settlement.
4. See other recommendations in the reports.

Figure 4-2: Sketch of Rockfill Pad & Thermal Insulation

4.3 Bearing Capacity

The allowable bearing capacity of the tunnel foundation is estimated based on the following assumptions:

- A factor of safety of 2.5 is applied to the ultimate bearing capacity to obtain the allowable bearing capacity.
- The foundations will be constructed on an engineered rockfill pad. An internal friction angle of 40° and a cohesion of zero are assumed. The underlying soil (silt) has an internal friction angle of 30° and a cohesion intercept of zero. The other detailed parameters for the rockfill and underlying soil are listed in Appendix A4.
- The footing size of 6.4 m width is used for the bearing capacity check.
- The foundation bearing capacity was checked for the following scenarios:
 - (a) Bearing capacity of a two-layer foundation system with a top rockfill layer and an underlying native soil layer. The parameters for the rockfill and underlying soil are listed in Figure 4-2. A weighted average friction angle for the two-layer foundation is to be calculated as per the recommendation by Bowles (1988).

$$\phi = \frac{d_1\phi_1 + (H - d_1)\phi_2}{H}$$

Where the influence depth $H = 0.5 \times B \times \tan(45 + \phi_1 / 2)$, where ϕ_1 is the friction angle for the top layer, ϕ_2 for the bottom layer, d_1 is the thickness of the top layer, B is the footing width.

- (b) Bearing capacity of the underlying soil. The bearing capacity will be checked in two sub-scenarios: (b1) bearing capacity as per friction shear strength (friction only) and (b2) bearing capacity as per frozen bonding strength (cohesion only).

Meyerhof's general bearing capacity equation (Das, 2007) was used to calculate the bearing capacity. Meyerhof's equation is (i.e. for zero cohesion):

$$q_u = qN_qF_{qs}F_{qd} + \gamma'BN_yF_{ys}F_{yd} \quad (\text{Equation 1})$$

where q is the surcharge load at the bottom of the foundation, N_q and N_y are bearing capacity factors, B is the foundation width, F_{qs} and F_{rs} are shape factors, and F_{qd} and F_{yd} are depth factors.

4.3.1 General

In a summary, the 3 m thick rockfill pad will satisfy the bearing capacity requirements, as summarized in the table below, given that the temperature of underlying permafrost is below minus 7°C (-7°C).

It is noted that the allowable bearing capacity in this section was estimated as per the ultimate limit state. The settlement analyses are presented in Section 4.5 to address the footing performance in the service limit state.

4.3.2 **Scenario (a) – Two-Layer Foundation**

Using Eqn. 1, the allowable bearing capacity of the two-layer system is 900 kPa, satisfying the required design load (750kPa).

4.3.3 **Scenario (b1) – Underlying Soil (Friction Only)**

This scenario checked the bearing capacity as per the friction angle of the silt (30 degree). The allowable bearing capacity is 1100 kPa, using the 2:1 stress distribution rule.

4.3.4 **Scenario (b2) – Underlying Soil (Permafrost Bond Strength Only)**

For frozen permafrost, the allowable bearing capacity below the footing is estimated to be 800 kPa, using (1) the 2:1 stress distribution rule and (2) the allowable permafrost bearing capacity of 560 kPa at a temperature below -7°C (see Ref. 5).

$$q_{allow} = 560kPa \times [(3m + B)/B] \approx 800 kPa$$

4.3.5 **Summary**

The above analyses show that the calculated allowable bearing capacities for all three cases are higher than the required bearing pressure of 750 kPa and thus meets the bearing capacity requirement.

Table 4-1: Bearing Capacity Assessment Summary – Stockpile Reclaim Tunnel

Case	Case Description	Allowable Bearing Capacity (kPa)	Required Bearing Capacity (kPa)
Case A	Rockfill and Soil	900	750
Case B1	Underlying Soil (Friction Strength)	1100	750
Case B2	Underlying Soil (Permafrost Bond Strength)	800	750

4.4 **Thermal Analyses**

A thermal analyses were performed to investigate the temperature regime in the foundation below the tunnel. Appendix A3 summarizes the methodologies and details of the thermal analyse. Figure B2-1 presents the general material and boundary conditions for the stockpile reclaim tunnel.

- (1) Case Without Insulation. Without insulation, the temperature of the underlying permafrost is about -3°C to -5°C to in the summer (see Figure B2-2 for the temperature contours 2 years after construction and Figure B2-3 for 20 years after construction). This does not satisfy the temperature requirement of -7°C in the previous section.
- (2) Case With Insulation. In this case, insulation pad is used to control the temperature of permafrost of the underlying silty sand. With a 150 mm thick insulation pad, the temperature of underlying permafrost can be maintained to be below -7°C (see Figure B2-4 for the temperature contours 2 years after construction and Figure B2-5 for 20 years after construction), which satisfies the temperature requirement. It is noted that insulation

pad can not be placed directly below the footings as the high footing bearing pressure exceeds the allowable capacity of the insulation pad.

As such, a minimum 150 mm thick insulation pad is required to control the permafrost temperature below -7°C , which provides sufficient bearing capacity for the footing.

4.5 Settlement Analyses

The placement of ore stockpile and the tunnel will produce compression of the foundations and cause settlement including long-term creep. Deformation analyses were conducted to assess the deformation of the tunnel foundation. Appendix A4 summarizes the methodologies and parameters for the settlement analysis. Appendix B3 summarizes model configurations and results of the settlement analyses for the stockpile reclaim tunnel.

The following cases were analyzed for the stockpile reclaim tunnel:

- Case 1: An axisymmetric 2D model was used in the analyses to evaluate the settlement profile along the longitudinal direction of the tunnel. The axisymmetric model can account for the three-dimension (3D) effect of the conical shape for the ore stockpile. The tunnel configuration has to be simplified in the axisymmetric model to satisfy the requirement of an axisymmetric geometry.
- Case 2: A plane strain 2D model with the actual tunnel configuration was used to evaluate the settlement profile along the cross-section of the tunnel.
- Case 3: A plane strain 2D model with the simplified tunnel configuration was used to assess the impact of the simplified tunnel configuration, in comparison with the model with the actual tunnel configuration (Case 2).
- Case 4: An axisymmetric 2D model was used for a 20 m thick silt deposit instead of 14 m in Case 1, which is inferred from the silt as per BH 17-M010, about 40 m to 80 m away from the tunnel.

4.6 Settlement Results

A design settlement profile along longitudinal direction of the tunnel is recommended as shown in Figure 4-3. The design settlement is based on the analyses results of Case 4 (20 m silt case), which corresponds to about 1.5 times of the settlement of the Case 1 (14 m silt case). The results should be reviewed as per the findings of the on-going geotechnical investigation at the site.

The design settlement profile is the best-estimated settlement without the safety factor applied as the serviceability limit state assessment is performed using un-factored loads and corresponding un-factored settlement (Canadian Foundation Design Manual, 2006).



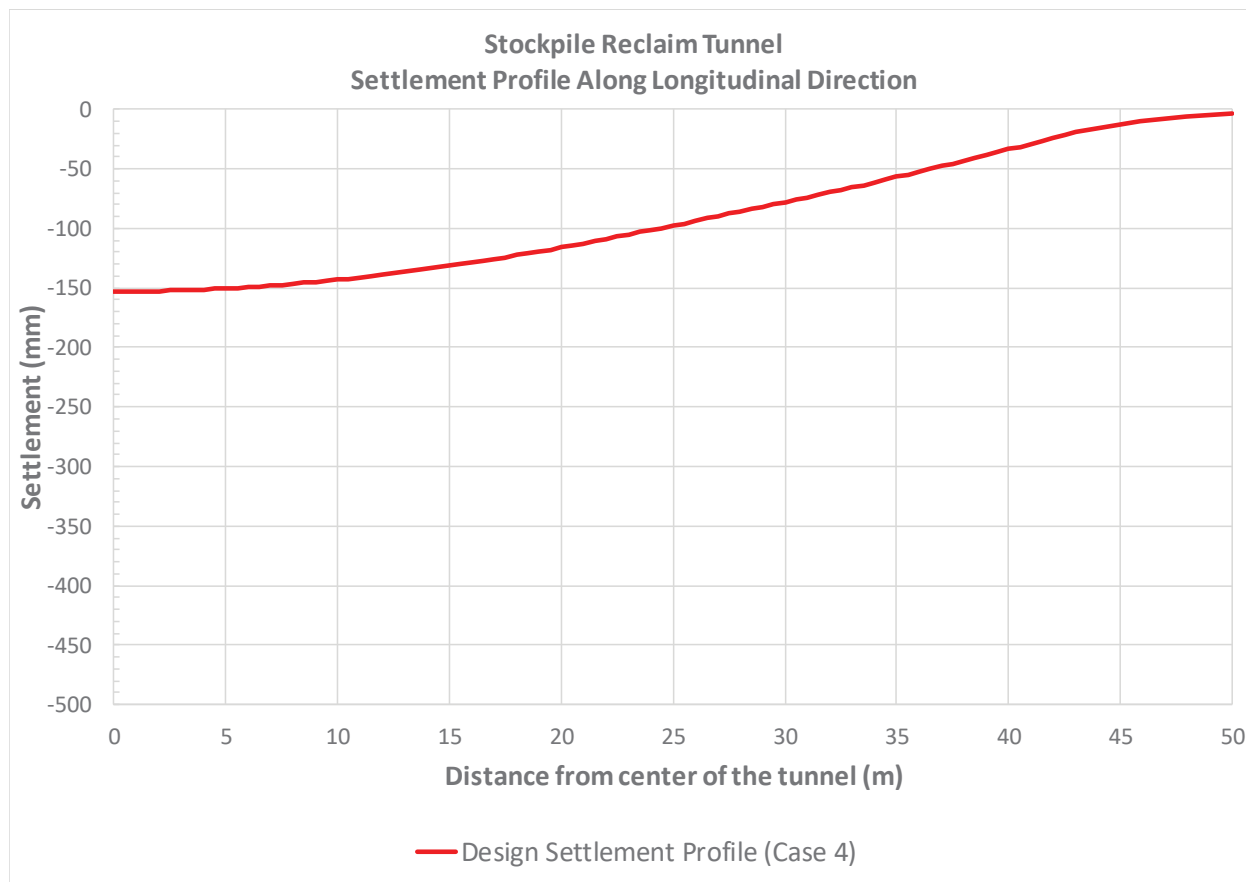


Figure 4-3: Settlement Profile along Longitudinal Direction – Stockpile Reclaim Tunnel

The following summarizes the results of all cases:

Case 1: Figure B3-1B shows the predicted vertical displacement along the longitudinal direction of the tunnel in axisymmetric model. The results show that the settlement is largest at the stockpile centre and gradually reduces approaching the toe of the stockpile. The total settlement at centre is about 110 mm.

Case 2: Figure B3-2B shows the predicted settlement displacement along the cross-section of the tunnel. As expected, the maximum settlement in Case 2 (about 130 mm) is higher than that of Case 1. The plane strain model in Case 2 tends to overestimate the settlement for a conical shape stockpile due to its inherent assumption of an infinite long model.

Case 3: Figure B3-3B shows the results of the plane strain model with a simplified tunnel configuration. Figure B3-5 presents a comparison between Case 2 and Case 3, showing Case 3 with the simplified tunnel configuration yields a similar and slightly larger settlement than Case 2 with the actual tunnel geometry. It shows that the simplification of tunnel configuration appears conservative in the settlement analysis. As such, the axisymmetric model with the simplified tunnel configuration is used as the base case to assess the settlement profile.

Case 4: Figure B3-4B presents the results from Case 4 as a sensitivity study for the silt thickness. It shows that the total settlement increases to about 150 mm for a 20 m thick silt deposit, approximately 50% higher than Case 1, as shown in Figure B3-6. It shows the foundation settlement is sensitive to the silt thickness. The elastic component of the total settlement is about 20 mm to 30 mm, which will occur during construction and initial ore placement. The creep settlement is expected to occur during the 20 year design life. Figure B3-7 provides an estimate of creep settlement versus time.

4.7 Monitoring/ Maintenance Program

A monitoring program is recommended to be carried out during the life of the project to track the performance of the stockpile and the reclaim tunnel and provide information for maintenance, if required. As part of maintenance program, surveys shall be performed twice a month during construction and may be reduced to a lower frequency during operation, depending on the actual performance. The design team should review the monitoring data on a regular basis.

The following provides a list of monitoring requirements. A detailed monitoring plan is beyond the scope of this report and should be developed separately.

1. Ground temperature cables: Two ground temperature cables (upper and lower) at each of two selected cross sections.
2. Survey inside the tunnel: four survey plate (two at the footing and two at the wall) at each of selected cross sections.
3. Surface survey points (survey monuments) on ground surface.
4. Temporary survey monuments: The survey monuments are to monitor the settlement after the tunnel installation and may be demobilised prior to the ore placement during operation.
5. Inclinator/Thermistor (optional). This monitoring equipment may be required as per the review of the early stage monitoring data from the temperature cable and survey data.

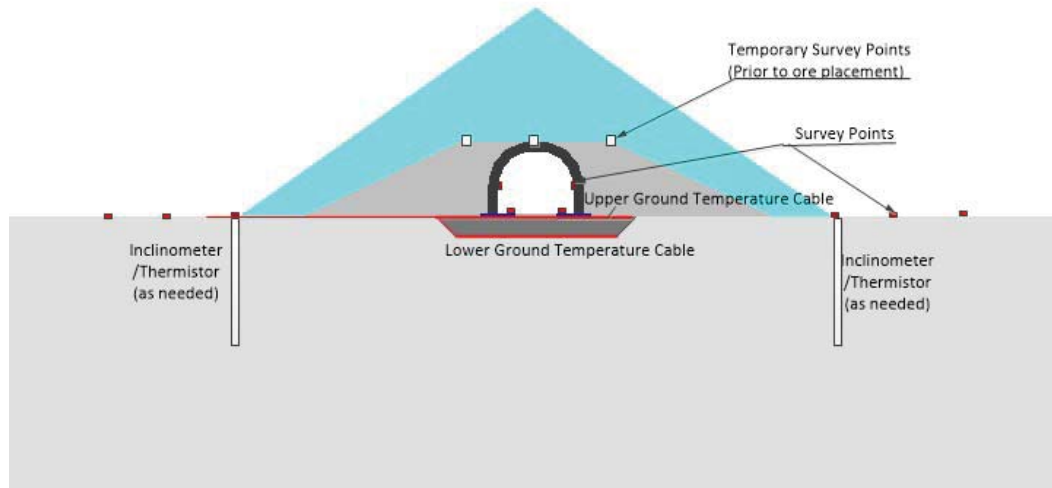


Figure 4-4: Monitoring Requirements

4.8 Assumptions and Limitations

The following presents the assumptions and limitations for the settlement analyses:

- (1) The creep parameters for permafrost were estimated from the literature test data on the soil with similar properties (soil type, ice content, loading range, and temperature range). However, site-specific tests (laboratory or field tests) or model calibration using the monitoring data of the on-site facilities are required to verify and confirm these design parameters.
- (2) Silt thickness is inferred as per the finding from BH 17-M010. Further investigation at the location of the structure is recommended to confirm/update this assumption.
- (3) A low ice content till is below the silt layer in the borehole of BH 17-M010. Further investigation is recommended to confirm the depth and the properties of the till layer.
- (4) It is understood that the tunnel footing information (load and size) may be not finalized. For any change of the footing load or footing size, the settlement/thermal analyses should be re-checked to ensure the sufficient bearing capacity and provide an update for the long-term settlement estimation.
- (5) The tunnel structures are to be designed by a third party. The properties of tunnel structure assumed in the model are to be reviewed/updated as the tunnel design becomes finalized for a more accurate result.

4.9 Recommendations – Stockpile Reclaim Tunnel



4.9.1 Construction

The construction of the foundation is preferred to be carried out in cold seasons, i.e., late fall to early spring (i.e., November to April). The construction in warm seasons (June to September) should be avoided if possible as it may disturb/thaw the native permafrost. For stockpile reclaim tunnel foundation, the underlying soil consists of silt permafrost, which should be carefully managed during construction, particularly in warm seasons.

If the schedule doesn't allow a cold season construction, the foundation construction should be carefully planned and be executed in an efficient way to minimize the foundation base exposure time and the risk of disturbing permafrost. Detailed recommendations will be provided as per the construction. As minimum, the following should be considered in the construction planning.

1. Timely replacement to minimize the permafrost exposure. Leave the blasted permafrost soil in place as a thermal protection layer until the excavation/backfill construction is ready to carry out. Do not exposure the native permafrost for an extended period.
2. Stage the construction. Excavate and backfill in benched sections from one end to the other to minimize the exposure of the native permafrost.
3. Control water. Provide diversion ditches/berm, dewatering trench, and sump and pump equipment to effectively control water inflow during construction.
4. Schedule the construction in dry weeks.
5. The excavation slope may be further flattered. Sloughing of slope should be expected and a maintenance program should be carried out to address the issue.
6. A qualified engineer should be on site supervising the construction to ensure QA/QC.

4.9.2 Excavation

Temporary excavation is required for the rockfill foundation preparation. The cut and backfill should be carried out in cold seasons.

The overall slope of the temporary cut into the frozen permafrost is recommended to be 1.5 H:1 V or flatter. Insulation materials and locally flattening the slope will be required where ice and very ice-rich soil is encountered to protect the slope. Periodical inspection of the cut slope is required during construction.

Ground ice and very high ice rich soil, if encountered at the foundation base, shall be excavated and backfilled with compacted approved materials. Air drills or GPR surveys are recommended to be carried out after the exposure of the foundation to detect any ground ice / very ice rich soil below foundation base.

A qualified geotechnical engineer shall inspect and approve the foundation base prior to backfilling.

4.9.3 Backfill

The backfill materials should be free draining and non-frost susceptible to prevent the formation of ice lenses, which may cause frost action and significant damage to the footing and/or structure. Materials that are considered to be non-frost susceptible are with 0% to 1.5% particles by weight finer than 0.02 mm.

The rockfill pad materials should be crusher-run rockfills, satisfying the requirement of the project specifications and drawings. The recommended compaction requirements for the crusher-run rockfills, which may be used in the construction are provided below. Any ice or snow shall be removed efficiently during construction.

The rockfill placement and compaction for foundation shall be supervised by a full-time geotechnical engineer and the construction records should be retained for the lift thickness and compaction passes.

- TYPE 5 (crusher-run 32 mm minus material) or TYPE 3 (crusher-run 50 mm minus): the material must be placed in lifts not exceeding 200 mm and shall be compacted by minimum 5 passes of a minimum 15 ton vibratory roller with vibrations in the range of 1200 to 1500 vpm and the roller speed of about 2 mph (3.2 km/h). Alternatively the compaction should achieve a minimum of 100 percent of maximum dry density as determined by test method ASTM D698.
- TYPE 8 (crusher-run 150 mm minus): the rockfill must be placed in lifts not exceeding 500 mm. The placement shall avoid segregation and nesting of coarse particles. It shall be compacted by minimum 5 passes of a minimum 15 ton vibratory roller with vibrations in the range of 1200 to 1500 vpm and the roller speed of about 2 mph (3.2 km/h). Each lift must be “proof-rolled” prior to placing the subsequent lift.
- TYPE 12 (run-of-mine, typically 600 mm minus): the rockfill, if used, must be placed in lift not exceeding 1000 mm. The rockfill shall be compacted by minimum 5 passes of a minimum 15 ton vibratory roller with vibrations in the range of 1200 to 1500 vpm and the roller speed of about 2 mph (3.2 km/h). Alternative compactors such as heavy loaded rubber-tired haul trucks can only be used as per a written approval from the Engineer.

4.9.4 Drainage

Proper drainage is an important component to ensure a satisfactory performance of the structure.

- (1) A positive and efficient drainage should be provided inside the tunnel to avoid any ponding water or ice accumulation. The drainage design should account for the potential settlement of the tunnel.
- (2) Runoff collection and diversions systems should be provided to efficiently direct run off away from the structure. Grade the ground surface 2% away from the structure.

- (3) During construction of rockfill pad, provide efficient sump / pump equipment to drain any runoff during construction as needed.

4.10 Summary and Conclusions

The following summarizes the key findings and recommendations:

- This report provides the foundation improvement measures consisting of a rockfill pad and insulation pads, providing a bearing capacity of 750 kPa for the tunnel footing size up to 6.4 m wide. The expected settlement is presented in this report. Hatch shared the preliminary settlement profile with the equipment supplier (tkIS) in January 2018 and understood that the settlement profile is manageable.
- It is noted that a geotechnical investigation is on-going to verify the assumed silt thickness. The settlement assessment performed in this report should be reviewed/updated as per the findings from the investigation program.
- Monitoring programs and inspections are recommended to verify the ground temperature and long-term displacement to ensure the satisfactory performance of the reclaim tunnel. The monitoring data will also provide useful information for maintenance purposes.
- Laboratory creep tests (and/or field tests) are recommended to verify the design creep parameters and the long-term bearing capacity for the permafrost.
- Pile foundation, as an alternative, should be used if the settlement is not acceptable for the structures. The pile foundations will have a much higher construction cost than the rockfill pad and thermal insulation option. Mat foundation can also be considered to improve the integrity of the tunnel structure and minimize the risk of the differential settlement in the cross-section direction.

5. Crushing/Screening Plants

5.1 Structure

This section summarizes the foundation configuration design for the crushing and screening plants.

The general arrangement of the structures and the site profiles are shown on the drawings in Appendix C1.

Figure 5-3 and Figure 5-4 shows the general layout of the crushing plant footings, as per Drawing No. 4853005 by tkIS. The following summarizes Hatch's understanding of the foundations:

- The crushing plant will have three 22 m long by 2.66 m wide pontoon-type footings. The centre-to-centre spacing of the footings is 6.6 m.
- The screening plant will have three 29 m long by 3 m wide pontoon-type footings. The centre-to-centre spacing of the footings is 6.4 m.

- The foundations will be constructed on an engineered rockfill pad. An internal friction angle of 40° and a cohesion of zero are assumed.
- The underlying soil (sand / silt) has an internal friction angle of 30° and a cohesion of zero.
- The expected loading pressure at the footing is about 350 kPa.
- The rockfill mat contains groundwater at the ground level during melt periods.
- A factor of safety of 3 is applied to the ultimate bearing capacity to obtain the allowable bearing capacity. The higher factor of safety is used for the crushing and screening plant considering the impact of vibration.
- For the crushing plant, the rockfill pad a 1 m high berm above the existing ground is required.
- For the screening plant, the rockfill pad a 0.4 m high berm above the existing ground surface is required.

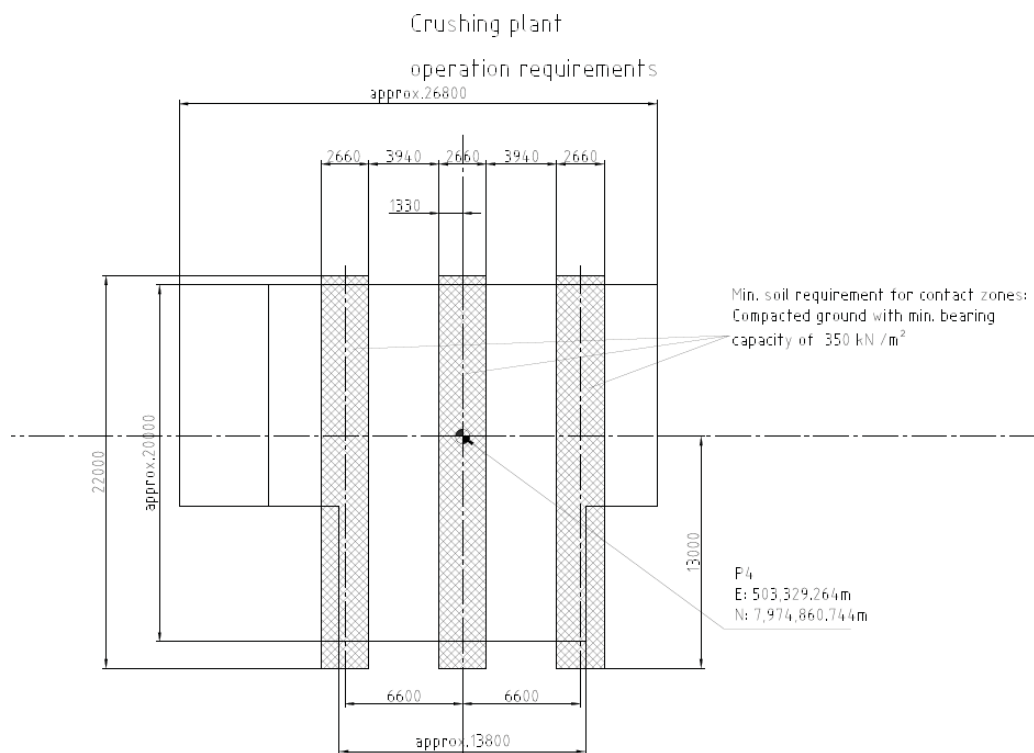


Figure 5-1: General Layout of Crushing Plant
(Information from Drawing No. 4853005, dated on July 07, 2017)

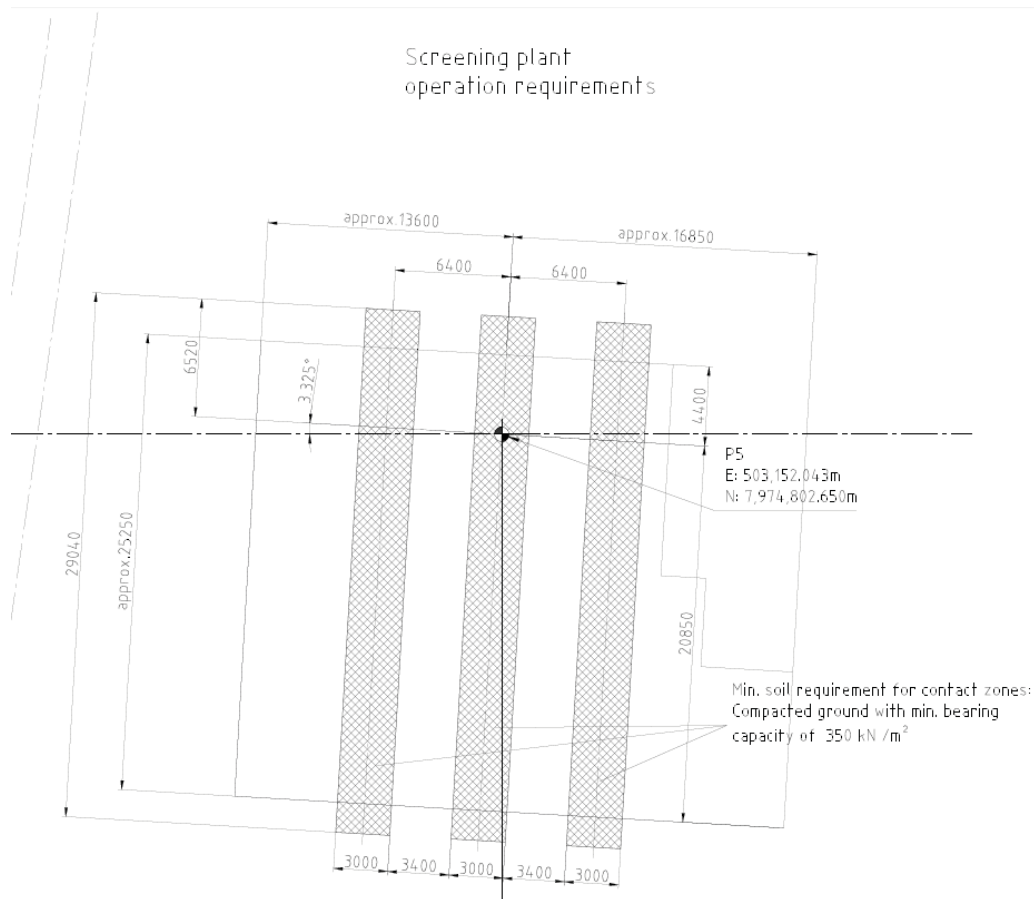


Figure 5-2: General Layout of Screening Plant
(Information from Drawing no. 4853005, dated on July 07, 2017)

5.2 Foundation Configurations

The rockfill foundation configurations for the crusher and screening plant are illustrated in the following figures.

- For the crushing plant site, the rockfill mat consists of a 1 m berm above ground surface and a 2 m cut and fill pad below ground surface.
- For the screening plant site, the rockfill mat consists of a 0.4 m berm above ground surface and a 2.6 m cut and fill pad below ground surface.

Figure 5-3 and Figure 5-4 show a preliminary configuration for the crushing plant and screening plant foundation respectively. The rockfill pads were designed to provide sufficient bearing capacity for the footing loads and to constrain the active zone within the rockfill. Insulation pad is not suitable to be used for the crushing and screening plant foundation considering the impact of vibration. Styrofoam HL requires a factor of safety of 5 to 10 for vibration loads and allows a very low bearing pressure from 40 kPa to 80 kPa for Styrofoam HL 60.

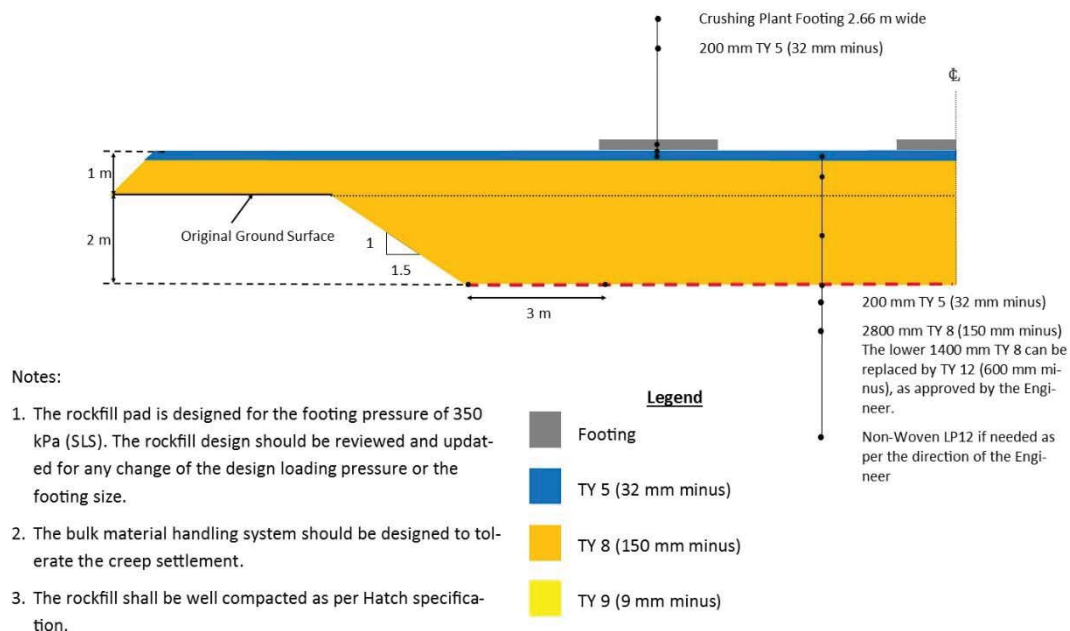


Figure 5-3: Foundation Configuration Sketch for Crushing Plant

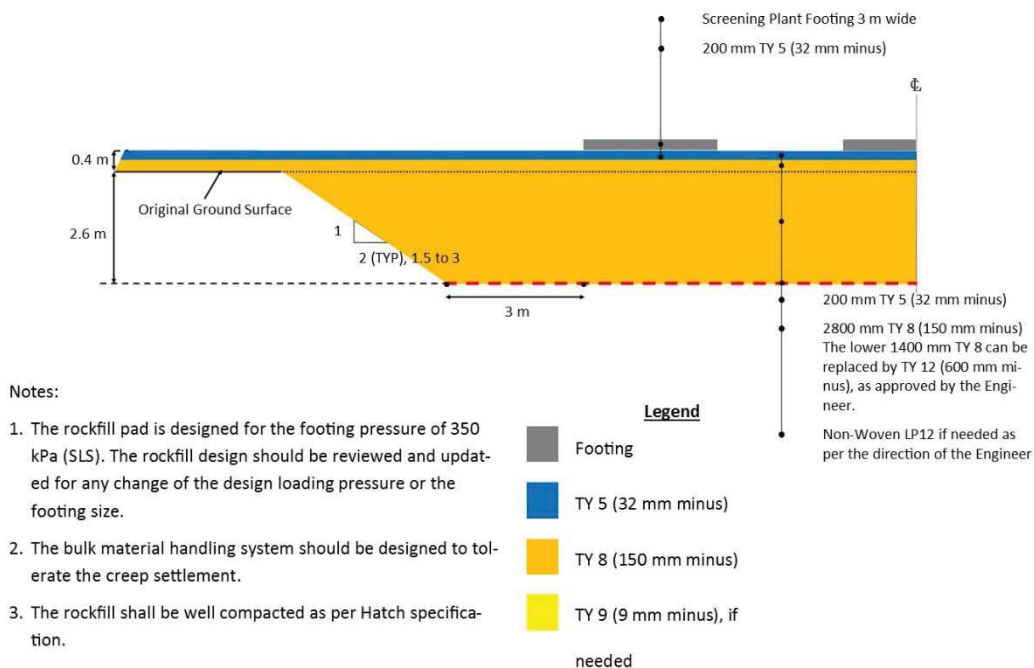


Figure 5-4: Foundation Configuration Sketch for Screening Plant

5.3 Bearing Capacity

The allowable bearing capacity for the crushing and screening plants was evaluated as per the three scenarios described in Section 4.3. The following table summarizes the calculated allowable bearing capacity, indicating that the proposed rockfill pad satisfies the bearing requirement:

Table 5-1: Bearing Capacity Assessment Summary Below Footings

Case	Case Description	Crushing Plant (kPa)	Screening Plant (kPa)	Required Bearing Capacity (kPa)
Case A	Rockfill and Soil	450	350	350
Case B1	Underlying Soil (Friction Strength)	>500	>500	350
Case B2	Underlying Soil (Permafrost Bond Strength)*	350	400	350

Note: *The bearing capacity below footings was estimated as per the allowable bearing capacity of underlying permafrost soil, i.e., 160 kPa at – 1°C temperature for the crushing plant and 200 kPa at – 1.5°C temperature for the screening plant (as per SNiP, 1988 with a factor of safety of 2.5).

5.4 Thermal Analyses

The thermal analyses were performed to investigate the temperature regime in foundation. Appendix A3 summarizes the methodologies and details of the thermal analyse. Figure C2-1 and Figure C2-6 presents the thermal model for the crushing plant and the screening plant respectively.

The temperature of the soil below rockfill pad is shown in Appendix C. The following summaries the results.

- The active zone is effectively restrained within the rockfill pad
- For the crushing plant, the underlying soil temperature ranges from -2°C to -1°C (see Figure C2-2 to Figure C2-3)
- For the screening plant, the underlying soil temperature ranges from -2°C to -1.5°C (see Figure C2-5 to Figure C2-6)
- The thaw settlement risk is considered low for the underlying permafrost, as the rockfill preserve the underlying permafrost below -1°C for both crushing and screening plants. The salinity measurement from BH 17-M010 is 3 ppt at 0.9 m depth and 13 ppt at 5 m depth, corresponding to a freezing point of -0.2°C and -0.7°C, respectively.

5.5 Settlement Analyses

The loads of crushing/screening plants will produce compression of the foundations and cause settlement including long-term creep. Deformation analyses were conducted to assess the foundation settlement. Appendix A4 summarizes the methodologies, and parameters of the analyses.

The following cases were analyzed:

- Case 1: A plane strain 2D model was used in the analyses to evaluate the settlement profile along the cross-section of the plant. The footing loads were modeled using surcharge. The stiffness of the plant is not available to Hatch and is thus conservatively ignored.
 - ♦ The subsurface configuration below the crushing plant consists of rockfill, sandy deposit to 3.5 m depth, 14 m thick silt, and till.
 - ♦ The subsurface configuration below the screening plant consists of rockfill, sandy deposit to 3 m depth, 14 m thick silt, and till.
- Case 2: This case is same with Case 1 except for the 28 m thick silt deposit instead of 14 m in Case 1.

5.6 Settlement Results

The design total settlement profiles along cross-sections are shown in Figure 5-5 and Figure 5-6 for crushing and screening plants respectively. It is noted that the settlement analyses assumes a flexible structure. For a rigid structure, the footing settlement is factored by a structure-rigidity settlement coefficient of 0.93 (Das, 1999). As such, the design total settlements are about 80 mm and 100 mm for the crushing plant and the screening plant respectively assuming a rigid structure.

The design settlement profile is the best-estimated settlement without the safety factor applied as the serviceability limit state assessment is performed using un-factored loads and corresponding un-factored settlement (Canadian Foundation Design Manual, 2006).

The total settlement includes both the elastic and creep settlement components. The elastic settlement due to the plants' self-weight will occur during installation and construction.

Appendix C3 summarizes the model configuration and the results of the settlement analyses.



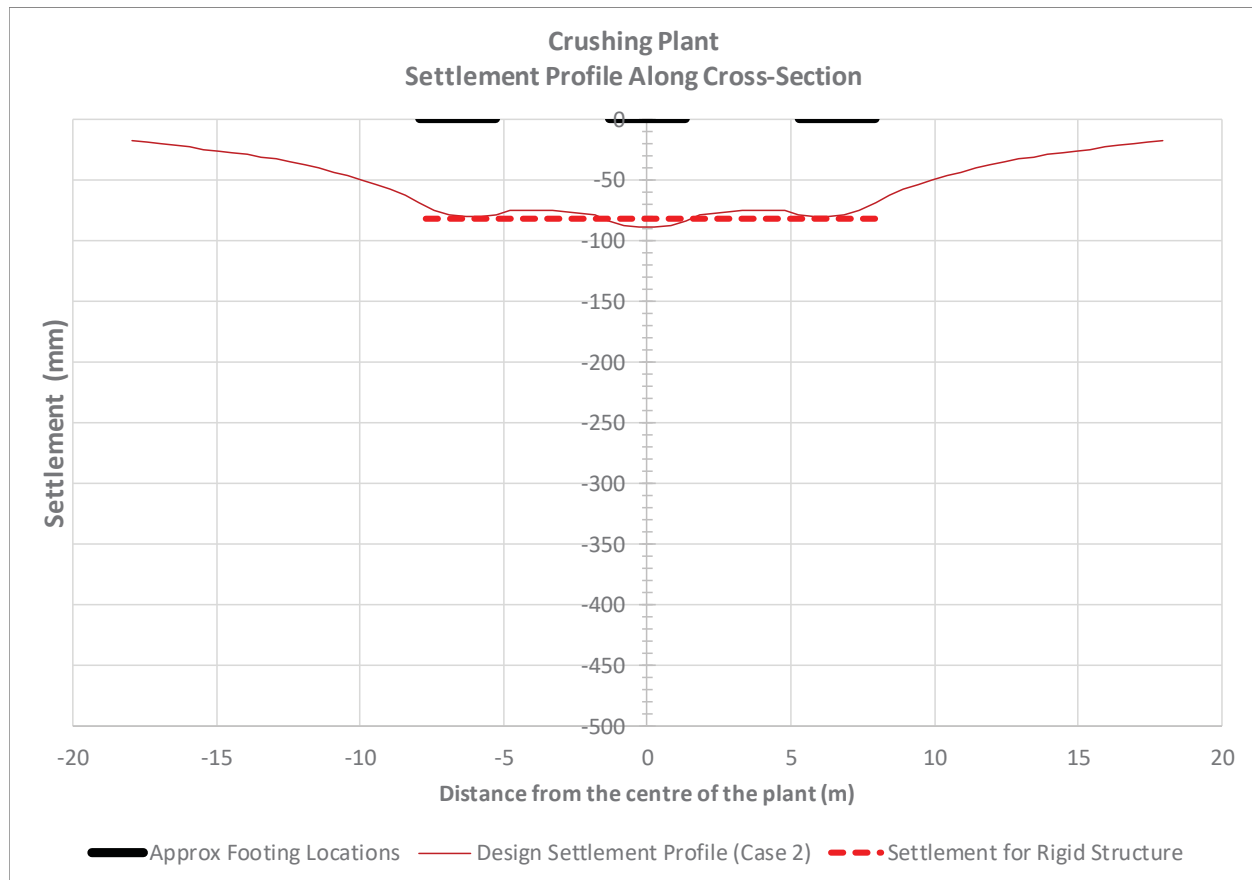


Figure 5-5: Settlement Profile in Cross-Section – Crushing Plant

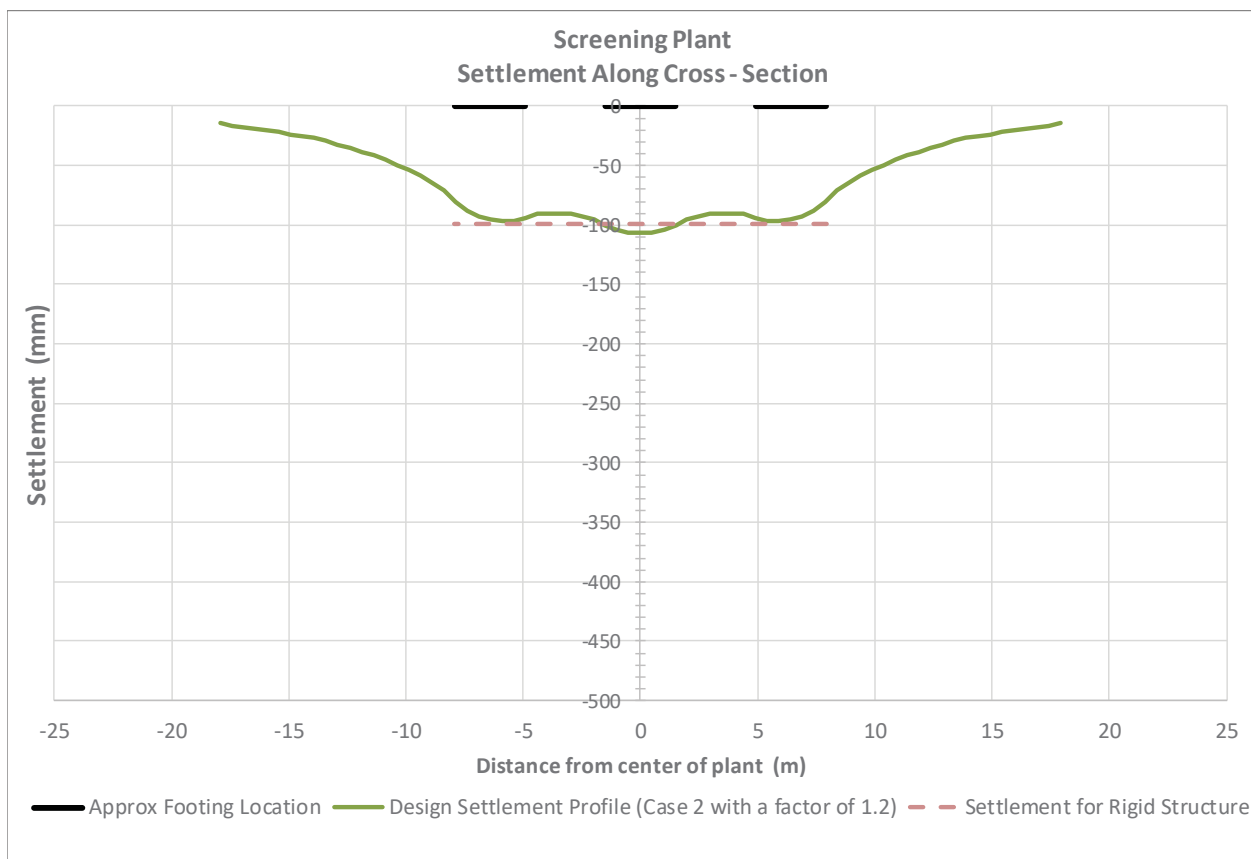


Figure 5-6: Settlement Profile in Cross-Section – Screening Plant

5.6.1 *Crushing Plant Settlement*

The total settlement contour of the crushing plant is shown in Figure C3-2 and Figure C3-3 in Appendix C3 for Case 1 and Case 2, respectively.

1. The total settlement below the footings ranges from 60 mm to 70 mm for Case 1, as shown in Figure C3-4.
2. The elastic (instantaneous) component is about 10 mm to 20 mm. This component will occur during installation/construction.
3. The creep settlement below the footings for Case 1 is about 40 to 50 mm.
4. The thicker silt layer (28 m) in Case 2 yield a larger footing settlement ranging from 80 mm to 90 mm, about 30% more than Case 1 with a 14 m thick silt layer.
5. The creep settlement versus time is shown in Figure B3-7, where the settlement is assumed in a power-law relationship with time, where the exponent ranges from 0.3 to 1.

5.6.2 **Screening Plant Settlement**

The settlement of the screening plant is shown in Figure C3-6 to Figure C3-8 for Case 1 and Case 2. The calculated settlement magnitude for the screening plant is very similar to those for the crushing plant. The design settlement profile for the screening plant was developed by applying a ratio of 1.2 to the calculated settlement, considering the more uncertainty of the silt layer due to the further distance of the screening plant (400 m) to the borehole BH 17-M010 than that (150 m) for the crusher plant.

5.7 **Monitoring Program**

A monitoring program is preferred to keep track the settlement performance of the plants. The monitoring program will consist of survey points marked on the footings of the plants.

5.8 **Assumptions and Limitations**

The following presents the assumptions and limitations for the settlement analyses:

- The creep parameters for permafrost were estimated from the literature test data on similar permafrost (soil type, ice content, loading range, and temperature range). However, site-specific tests (lab or field tests) or model calibration using the monitoring data of the on-site facilities are required to verify and confirm these design parameters.
- Silt thickness of 14 m is inferred as per the finding from BH 17-M010. Further investigation at the location of the structure is recommended to confirm/update this assumption.
- A low ice content till is expected below the silt layer in the borehole of BH 17-M010. Further investigation is recommended to confirm the depth and the properties of the till layer.
- The footing loads were simulated as surcharges in the finite element model (equivalent to the flexible footing). The calculated settlement from the model is conservative. The stiff frame structure would yield a more uniform and less settlement.
- The impact of vibration to the settlement of permafrost has not been well studied in literature. The settlement factor was used to account for the uncertainties.

5.9 **Recommendations – Crushing/Screening Plants**

The recommendations for foundation construction, excavation, backfill and drainage in Section 4.9.1 are applicable for the crushing/screening plants' foundation.

5.10 **Design Update**

A design update was shown in Figure 5-7 and Figure 5-8 consisting an insulation layer added below the footings. It is noted that the insulation pad can not be placed directly below the footing to avoid damage of the insulation under the dynamic loads (consequently creep settlement).



The main objective of the insulation layer is to protect the permafrost. It also helps raise the permafrost line near the native soil to block the potential water inflow. The conclusions of the settlement and thermal analyses remains valid for the updated configuration.

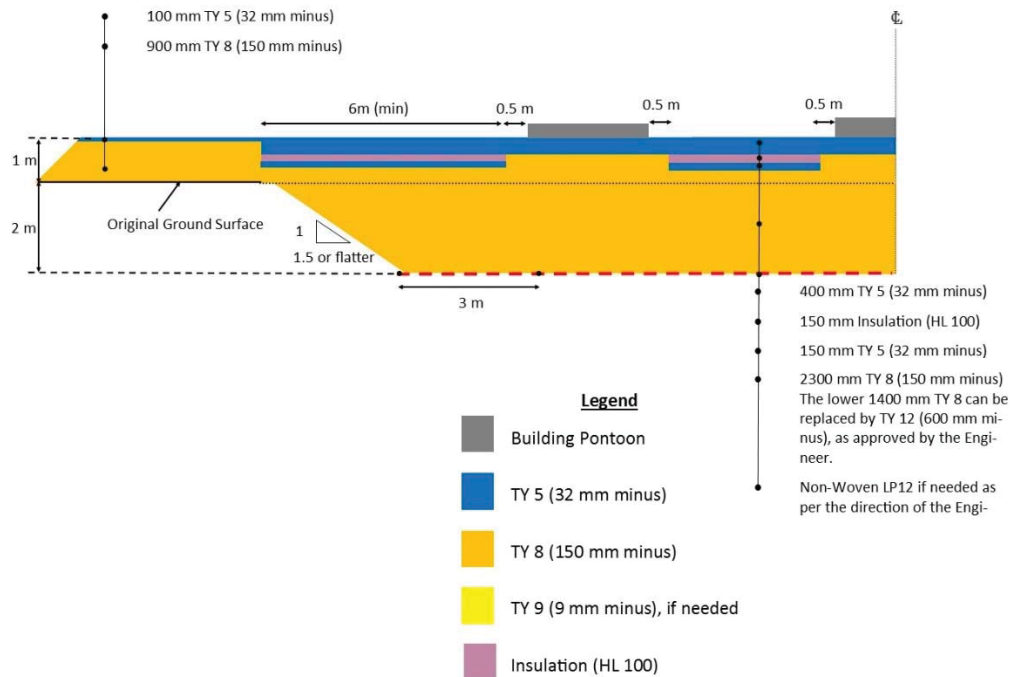


Figure 5-7: Foundation Configuration Sketch for Crushing Plant (updated)

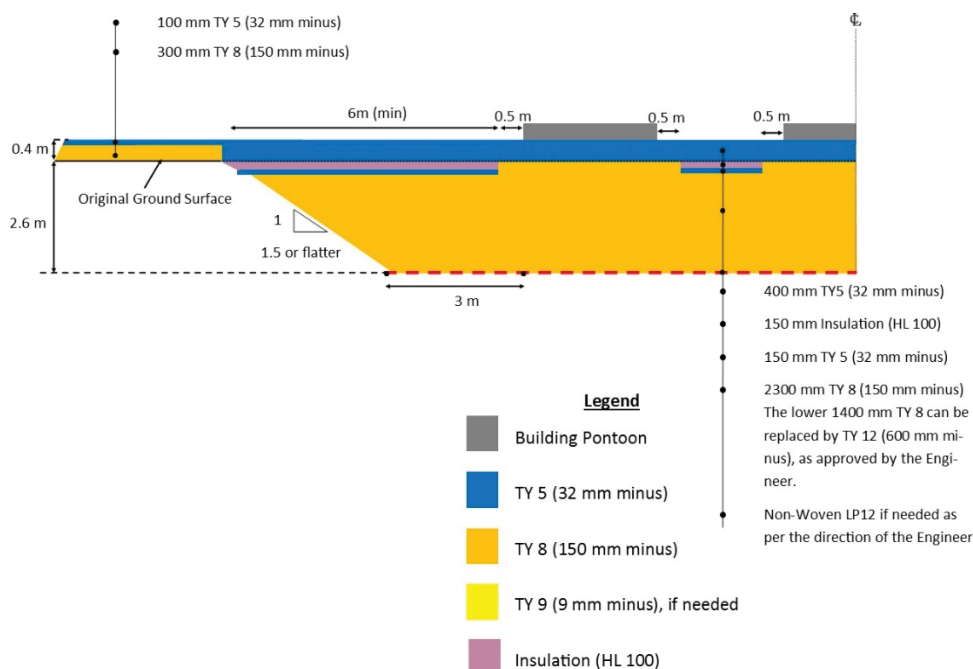


Figure 5-8: Foundation Configuration Sketch for Screening Plant (updated)

5.11 Summary and Conclusions

The following summarizes the key findings and recommendations:

- The foundation improvement consists of a rockfill pad, providing a bearing capacity of 350 kPa for the footings of the crushing and screening plants.
- The expected settlement is presented in this report. The bulk material handling system should be designed to mitigate the estimated settlement. A staged installation may be considered to mitigate the settlement by taking advantage of the waiting time from the plant installation and the installation of the tie-in component connecting to the conveyor system.
- It is noted that a geotechnical investigation are on-going to verify the assumed silt thickness. The settlement assessment performed in this report should be reviewed/updated as per the findings from the investigation program.
- Monitoring programs and inspections are required to track the long-term displacement to ensure the satisfactory performance of the structures. The monitoring data will also provide useful information for maintenance purposes.
- Laboratory creep tests (and/or field tests) are recommended to verify the design creep parameters and the long-term bearing capacity for the permafrost.

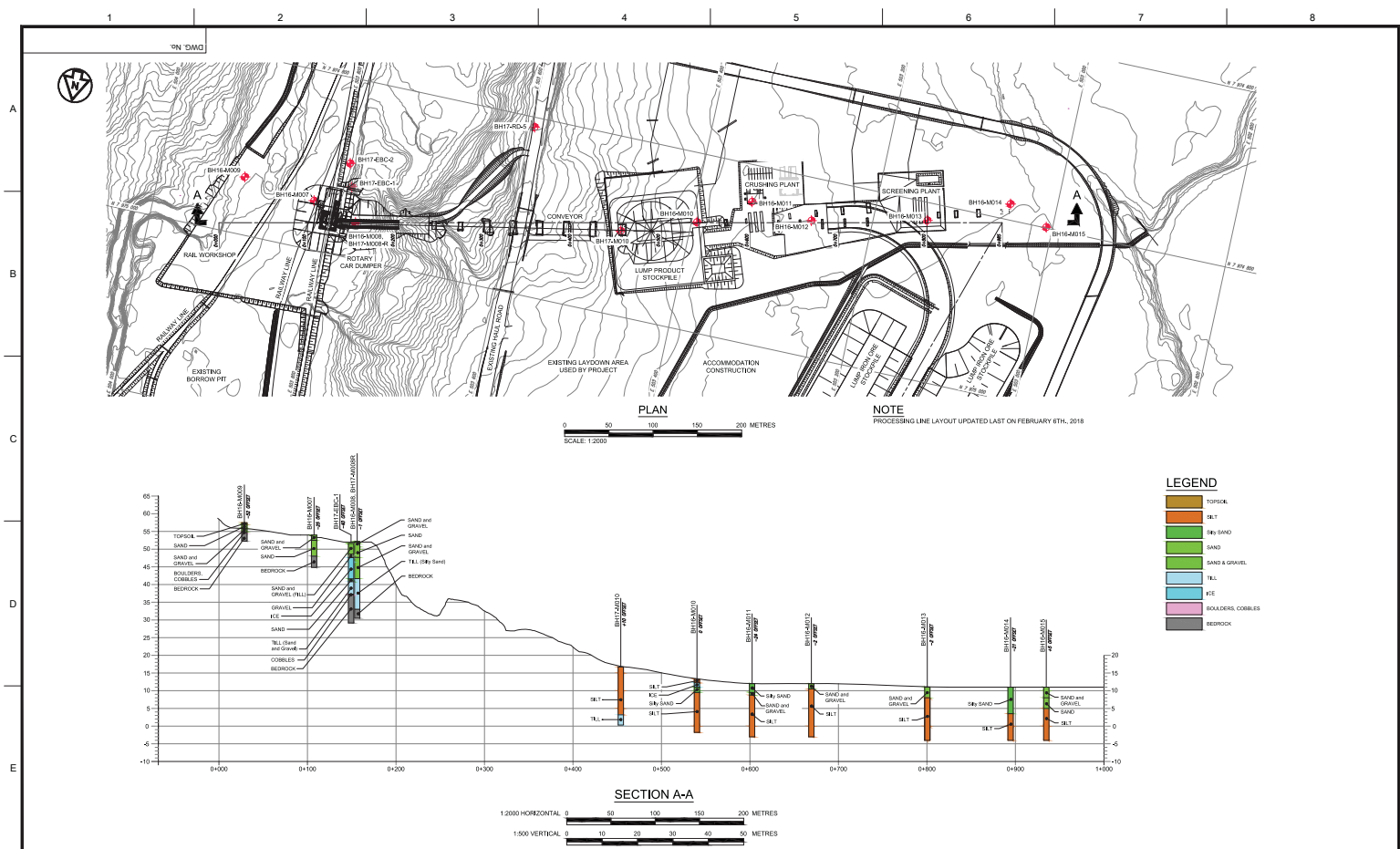
- Pile foundation (e.g., adfreeze piles), as an alternative, should be used if the settlement is not *acceptable* for the structures. The pile foundations likely have a much higher construction cost than the rockfill pad and insulation pad option.

6. References

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14. SNiP 1988. Base and Foundations On The Permafrost Soil. 2.02.04-88. USSR State Building And Construction Committee, Moscow.

Appendix A1

Geographical Profile



			DATE		HATCH		Baffinland	
SIGNATURE			DESIGNER		T. BERENSON		Baffinland EXPANSION 12 MTPA MINE OPTION PRE FEASIBILITY STUDY	
ENGINE NUMBER			CHECKER		T. BER		2018-02-07	
REVISION DATE			DESIGN COORD		G. GU		PORT SITE PROCESSING LINE GEOLOGICAL PROFILE	
ORIGINAL DATE			RESP. ENG.		G. GU		DWG. No. H352034-GEOSKT-229-292-0011	
REGISTERED PROFESSIONAL			ENG. MANAGER		G. GU		SCALE 1:2000	
			PROJ. MANAGER		G. GU		DWG. No. H352034-GEOSKT-229-292-0011	
			No.		DESCRIPTION		BY	
					REVISIONS		CHKD	
							DATE	
							ROLE	
							NAME	
							SIGNATURE	
							DATE	
							DRAWING APPROVAL STATUS	
							INTERNAL REVIEW	
							SCALE 1:2000	
							DWG. No. H352034-GEOSKT-229-292-0011	
							REV	
							A1	

Appendix A2

Borehole Data



BOREHOLE REPORT

BH17-10

Sheet 1 of 2

Client: Baffinland Iron Mines**Project No.:** H353004**Project:** Mary River Expansion Study Stage 2**Datum:** NAD 83**Location:** Transfer Conveyor**Platform:** 0**Contractor:** Boart Longyear**Rig Type/ Mounting:** MiniSonic Rig**Date Logged:** 10/29/2017**Driller:** Brent McAndrew**Hole Diameter (mm):** 100 mm**Date Reviewed:** 1/18/2018**Easting:** 503,476.0 m**Northing:** 7,974,905.0 m**Surface Elevation:** 17.00 m**Bottom Elevation:** 0.28 m**Total Depth:** 16.7 m**Logged By:** R.S**Reviewed By:** G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						SILT with Sand, trace Gravel up to 80 mm, brown, unfrozen to 1.6 m, occasional ice lenses up to 4 mm thick.	Nbe - Vs			0 25 50							
	16.0	1.0									26	10	42	48			
	15.0	2.0															
	14.0	3.0															
	13.0	4.0															
	12.0	5.0									19	10	35	55			
	11.0	6.0															
	10.0	7.0															
	9.0	8.0				SILT, trace to some Sand, trace Organics, thin layers, brown to greyish-brown with occasional thin black seam, frozen with some thin ice lenses from 10.3 to 10.6 m.	Nbe trace Vs				9	8	36	56			
	8.0	9.0									37	0	1	99			
	7.0	10.0															

Notes: BH collar elevation is estimated from Lidar information.



BOREHOLE REPORT

BH17-10

Sheet 2 of 2

Client: Baffinland Iron Mines**Project No.:** H353004**Project:** Mary River Expansion Study Stage 2**Datum:** NAD 83**Location:** Transfer Conveyor**Platform:** 0**Contractor:** Boart Longyear**Rig Type/ Mounting:** MiniSonic Rig**Date Logged:** 10/29/2017**Driller:** Brent McAndrew**Hole Diameter (mm):** 100 mm**Date Reviewed:** 1/18/2018**Easting:** 503,476.0 m**Northing:** 7,974,905.0 m**Surface Elevation:** 17.00 m**Bottom Elevation:** 0.28 m**Total Depth:** 16.7 m**Logged By:** R.S**Reviewed By:** G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
	6.0	11.0				SILT, trace to some Sand, trace Organics, thin layers, brown to greyish-brown with occasional thin black seam, frozen with some thin ice lenses from 10.3 to 10.6 m. <i>(Continued)</i>	Nbn trace Vs <i>(Continued)</i>			0 25 50							
	5.0	12.0									21	0	2	98			
	4.0	13.0									18	0	30	70			
	3.0	14.0				TILL, Sand, some Silt, some Gravel rounded to sub angular, well graded, biege to light grey, frozen.	Nbn				8	15	69	16			
	2.0	15.0															
	1.0	16.0									8	13	60	27			
	0.0	17.0				To Target Depth. Drillhole BH17-10 terminated at 16.7m.											
	-1.0	18.0															
	-2.0	19.0															
	-3.0	20.0															

Notes: BH colar elevation is estimated fro Lidar information.



BOREHOLE REPORT

BH16-M008

Sheet 1 of 3

Client: Baffinland Iron Mines**Project No.:** H352034**Project:** Mary River Expansion Study Stage 2**Datum:** NAD83**Location:** Milne Port Train Unloading**Platform:** Ground**Contractor:** Boart Longyear**Rig Type/ Mounting:** MiniSonic Rig**Date Logged:** 10/4/2016**Driller:** E.Beachamp**Hole Diameter (mm):** 96**Date Reviewed:** 2/10/2017**Easting:** 503,771.0 m**Northing:** 7,974,959.0 m**Surface Elevation:** 52.00 m**Bottom Elevation:** 30.66 m**Total Depth:** 21.3 m**Logged By:** UK**Reviewed By:** SH/WH

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery Sample Type	Moisture Content Profile							Other Tests
						SANDY GRAVEL: Rounded to sub angular gravel, coarse grained sand, well graded	Nf									
						SAND: Coarse to fine grained	Nf									
						3.00 m to 4.60 m: Some SILT	Nbn									
						SAND and GRAVEL: Coarse grained sand	Nf									
						6.90 m to 7.60 m: Zone of inferred cobbles										
						SILTY SAND, some GRAVEL: Fine to coarse, subangular gravel	Nbn									
						12.20 m to 12.60 m: GRAVELLY SILTY SAND										
						13.80 m to 15.40 m: SILTY SAND										
						Start of Coring at 18.8m. Continued on Rock Core Log sheet.										

Notes:



Sheet 1 of 2

Project No.: H352034

Datum: NAD83

Platform: Ground

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 10/4/2016

Driller: Samuel Flynn

Hole Diameter (mm): 96

Date Reviewed:2/10/2017

Easting: 503,904.0 m

Northing: 7,974,935.0 m

Surface Elevation: 57.50 m

Bottom Elevation: 52.32 m

Total Depth: 5.2 m

Logged By: MR

Reviewed By: SH/WH

[illegible]

Notes:



Sheet 1 of 1

Project No.: H352034

Datum: NAD83

Platform: Ground

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 12/9/2016

Driller: Michael Scott

Hole Diameter (mm): 96

Date Reviewed:2/10/2017

Easting: 503,394.0 m

Northing: 7,974,877.0 m

Surface Elevation: 13.30 m

Bottom Elevation: -1.90 m

Total Depth: 15.2 m

Logged By: MR

Reviewed By: SH/WH

[illegible]

Notes:



Sheet 1 of 1

Project No.: H352034

Datum: NAD83

Platform: Ground

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 12/4/2016

Driller: Michael Scott

Hole Diameter (mm): 96

Date Reviewed:2/10/2017

Easting: 503,339.0 m

Northing: 7,974,868.0 m

Surface Elevation: 12.00 m

Bottom Elevation: -3.20 m

Total Depth: 15.2 m

Logged By: MR

Reviewed By: SH/WH

[illegible]

Notes:



Sheet 1 of 1

Reviewed By: SH/WH

[illegible]

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Sheet 1 of 1

Reviewed By:	SH/WH
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[illegible]

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BOREHOLE REPORT

BH16-M014

Sheet 1 of 1

Client: Baffinland Iron Mines**Project No.:** H352034**Project:** Mary River Expansion Study Stage 2**Datum:** NAD83**Location:** Milne Port Tail Pulley**Platform:** Ground**Contractor:** Boart Longyear**Rig Type/ Mounting:** MiniSonic Rig**Date Logged:** 12/5/2016**Driller:** Michael Scott**Hole Diameter (mm):** 96**Date Reviewed:** 2/10/2017**Easting:** 503,052.0 m**Northing:** 7,974,782.0 m**Surface Elevation:** 11.00 m**Bottom Elevation:** -4.20 m**Total Depth:** 15.2 m**Logged By:** MR**Reviewed By:** SH/WH

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						GRAVELLY SILTY SAND: Grey to brown, angular to subangular gravel	Nf									
	-9.0	2.0								6	22	52	26			
						SILTY SAND: Grey	Nbn									
	-7.0	4.0														
										21	0	78	22			
	-5.0	6.0					Nf									
							Nbn									
	-3.0	8.0				SILT, some SAND: Dark grey, fine grained sand	Nf									
							Nbn									
	-1.0	10.0					Nf									
	-1.0	12.0														
	-3.0	14.0					Nbn									
	-5.0	16.0				To Target Depth. Drillhole BH16-M014 terminated at 15.2m.										
	-7.0	18.0														
	-9.0	20.0														

Notes:



BOREHOLE REPORT

BH16-M015

Sheet 1 of 1

Client: Baffinland Iron Mines**Project No.:** H352034**Project:** Mary River Expansion Study Stage 2**Datum:** NAD83**Location:** Milne Port Tail Pulley Alt.**Platform:** Ground**Contractor:** Boart Longyear**Rig Type/ Mounting:** MiniSonic Rig**Date Logged:****Driller:** Michael Scott**Hole Diameter (mm):** 96**Date Reviewed:** 2/10/2017**Easting:** 503,007.0 m**Northing:** 7,974,799.0 m**Surface Elevation:** 11.00 m**Bottom Elevation:** -4.20 m**Total Depth:** 15.2 m**Logged By:** MR**Reviewed By:** SH/WH

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
	9.0	2.0				SAND and GRAVEL, trace SILT, trace COBBLES: Light brown to grey, fine to coarse grained sand, rounded gravel	Nf			1	32	59	10			
	7.0	4.0				SAND, trace SILT: Light brown, fine to coarse grained sand,	Nf			14	15	71	14			
	5.0	6.0				SILT, some SAND: Dark grey to brown	Nbn									
	3.0	8.0	Vibrocure	H-Casing			Nf									
	1.0	10.0								24						
	-1.0	12.0														
	-3.0	14.0														
	-5.0	16.0								27						
	-7.0	18.0														
	-9.0	20.0														
						To Target Depth. Drillhole BH16-M015 terminated at 15.2m.										

Notes:



BOREHOLE REPORT

BH17-EBC-1

Sheet 1 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 9/19/2017

Driller: Brent McAndrew

Hole Diameter (mm): 100 mm

Date Reviewed: 1/26/2018

Easting: 503,783.4 m

Northing: 7,974,920.8 m

Surface Elevation: 51.59 m

Bottom Elevation: 29.92 m

Total Depth: 21.7 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
										0 25 50							
	50.6	1.0				FILL, Sand and Gravel. Material placed to create level drilling platform.	Unfrozen										
	49.6	2.0															
	48.6	3.0				GRAVEL with Silt, brown and grey, frozen.	Unfrozen										
	47.6	4.0				ICE, clear.	ICE										
	46.6	5.0															
	45.6	6.0				SAND, fine to medium, brown, frozen.	Nbn										
	44.6	7.0				ICE, clear, trace silt, trace fine sand, grey.	ICE										
	43.6	8.0															
	42.6	9.0															
	41.6	10.0				SAND, fine to medium, trace silt, light brown, frozen with a trace thin ice lenses.	Nbn-Vs										

Notes:



BOREHOLE REPORT

BH17-EBC-1

Sheet 2 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 9/19/2017

Driller: Brent McAndrew

Hole Diameter (mm): 100 mm

Date Reviewed: 1/26/2018

Easting: 503,783.4 m

Northing: 7,974,920.8 m

Surface Elevation: 51.59 m

Bottom Elevation: 29.92 m

Total Depth: 21.7 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						SAND and GRAVEL some Silt, brown.	Nbn			0 25 50							
	40.6	11.0									9						
	39.6	12.0									8						
	38.6	13.0									9						
	37.6	14.0				COBBLES and BEDROCK, (pulverized cobbles and bedrock), beige, dry powdery, with layers of brown silty sand and gravel, moist. Top of poor quality bedrock, 14.04 m					4						
	36.6	15.0				Start of Coring at 14.0m. Continued on Rock Core Log sheet.											
	35.6	16.0															
	34.6	17.0															
	33.6	18.0															
	32.6	19.0															
	31.6	20.0															

Notes:



BOREHOLE LOG

ROCK CORE FORMAT

BH17-EBC-1

Sheet 3 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear **Rig Type/ Mounting:** MiniSonic Rig **Bearing:** N/A **Date Logged:** 9/19/2017

Driller: Brent McAndrew **Hole Diameter (mm):** 100 mm **Plunge:** Vertical **Date Checked:** 1/26/2018

Easting: 503,783.4 m

Northing: 7,974,920.8 m

Surface Elevation: 51.59 m

Bottom Elevation: 29.92 m

Total Depth: 21.7 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Geological Unit	Rock Description ROCK TYPE; Grain size, texture and fabric, colour, general defect conditions, minor constituents.	Weathering/ Cementation	Estimated Strength						Is ₍₅₀₎ [UCS] MPa	Defect Spacing mm				RQD %	
									EH	VH	H	M	L	VL		EL	2000	600	200		
	40.6	11.0																			
	39.6	12.0																			
	38.6	13.0																			
	37.6	14.0					Resuming in Rock Core Format 14.0m.														
	36.6	15.0					Bedrock, Granitic Gneiss, reddish pink, hard to very hard. Fractures and joints filled with silty sand and clay.														
	35.6	16.0																			
	34.6	17.0																			
	33.6	18.0																			
	32.6	19.0																			
	31.6	20.0																			

Notes:



BOREHOLE LOG

ROCK CORE FORMAT

BH17-EBC-1

Sheet 4 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear **Rig Type/ Mounting:** MiniSonic Rig **Bearing:** N/A **Date Logged:** 9/19/2017

Driller: Brent McAndrew **Hole Diameter (mm):** 100 mm **Plunge:** Vertical **Date Checked:** 1/26/2018

Easting: 503,783.4 m

Northing: 7,974,920.8 m

Surface Elevation: 51.59 m

Bottom Elevation: 29.92 m

Total Depth: 21.7 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Geological Unit	Rock Description ROCK TYPE; Grain size, texture and fabric, colour, general defect conditions, minor constituents.	Weathering/ Cementation	Estimated Strength						Is ₍₅₀₎ [UCS] MPa	Defect Spacing mm				RQD %	
									EH	VH	H	M	L	VL		EL	2000	600	200		
	30.6	21.0			<																

85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm 1 mm clay sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
85° Jt Pl Sm Silt sn
10° Cz Ir Ro Silt
10° DI Ir Ro Silt
10° DI Ir Ro Silt
10° DI Ir Ro Silt

Notes:



BOREHOLE REPORT

BH17-EBC-2

Sheet 1 of 4

Client: B.I.M**Project No.:** H353004**Project:** Mary River Expansion Study Stage 2**Datum:** NAD 83**Location:** Rail Indexer Foundation**Platform:** Ground**Contractor:** Boart Longyear**Rig Type/ Mounting:** MiniSonic Rig**Date Logged:** 9/24/2017**Driller:** Brent McAndrew**Hole Diameter (mm):** 100 mm**Date Reviewed:** 1/26/2018**Easting:** 503,790.9 m**Northing:** 7,974,895.2 m**Surface Elevation:** 54.05 m**Bottom Elevation:** 32.21 m**Total Depth:** 21.8 m**Logged By:** R.S**Reviewed By:** G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
	53.1	1.0				SAND and GRAVEL with Silt and Cobbles. Gravel is well graded up to 75 mm, cobbles inferred from pulverized, dry, beige rock flour. Sand is brown. Unfrozen.	Unfrozen			0 25 50	1						
	52.1	2.0				SAND trace Silt, fine to medium, brown, frozen, (ice poor soil)	Nbn				6						
	51.1	3.0									28						
	50.1	4.0				SAND and GRAVEL, medium sand to medium gravel, angular, brown, frozen. (ice poor soil)	Nbn Nbn				21						
	49.1	5.0				GRAVEL with Sand trace Silt. Fine sand to coarse gravel, angular, brown and beige, frozen (ice poor soil)					9						
	48.1	6.0									10						
	47.1	7.0									7						
	46.1	8.0				GRAVEL with Silt, brown and grey, frozen. (ice poor soil)	Nbn				7						
	45.1	9.0				COBBLES and GRAVEL some Silt, trace Sand.					10						
	44.1	10.0															

Notes:



BOREHOLE REPORT

BH17-EBC-2

Sheet 2 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 9/24/2017

Driller: Brent McAndrew

Hole Diameter (mm): 100 mm

Date Reviewed: 1/26/2018

Easting: 503,790.9 m

Northing: 7,974,895.2 m

Surface Elevation: 54.05 m

Bottom Elevation: 32.21 m

Total Depth: 21.8 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						COBBLES and GRAVEL some Silt, trace Sand. (Continued)				0 25 50							
	43.1	11.0															
	42.1	12.0															
	41.1	13.0															
						Start of Coring at 13.3m. Continued on Rock Core Log sheet.											
	40.1	14.0															
	39.1	15.0															
	38.1	16.0															
	37.1	17.0															
	36.1	18.0															
	35.1	19.0															
	34.1	20.0															

Notes:



BOREHOLE LOG

ROCK CORE FORMAT

BH17-EBC-2

Sheet 3 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear Rig Type/ Mounting: MiniSonic Rig Bearing: N/A Date Logged: 9/24/2017

Driller: Brent McAndrew Hole Diameter (mm): 100 mm Plunge: Vertical Date Checked: 1/26/2018

Easting: 503,790.9 m

Northing: 7,974,895.2 m

Surface Elevation: 54.05 m

Bottom Elevation: 32.21 m

Total Depth: 21.8 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Geological Unit	Rock Description ROCK TYPE; Grain size, texture and fabric, colour, general defect conditions, minor constituents.	Weathering/ Cementation	Estimated Strength						Is ₍₅₀₎ [UCS] MPa	Defect Spacing mm			RQD %	
									EH	VH	H	M	L	VL		EL	2000	600		
	43.1	11.0																		
	42.1	12.0																		
	41.1	13.0																		
							Resuming in Rock Core Format 13.3m.													
	40.1	14.0					Bedrock, Granitic Gneiss, reddish pink, hard to very hard. Fractures and joints filled with silty sand and clay.												DI 10° DI Ir Ro 10° Cz Ir Ro Silt 10° Jt Pl Ro 3 mm clay sn 10° Jt Pl Ro Silt sn 10° Cz Ir Ro 65° Jt Pl Sm Silt Cz 10° Jt Pl Sm Silt 10° Jt Pl Sm Silt 10° DI Ir Ro Silt 10° DI Ir Ro Silt 10° DI Ir Ro Silt 10° DI Ir Ro Silt 10° DI Ir Ro Silt 10° DI Ir Ro Silt Cz 75° Jt Pl Sm 4mm Clayey sn 10° Jt Pl Sm Silt 10° Jt Pl Sm Silt sn Cz 75° Jt Pl Ro sn 10° Jt Pl Sm Silt sn 10° Jt Pl Sm Silt sn 5° Jt Pl Sm Silt sn 0° Jt Pl Sm Silt sn 0° DI Ir Ro 60° Jt Pl Sm Silt cg 0° DI Ir Ro 15° Jt Pl Sm Silt sn 20° Jt Pl Sm Silt sn 20° DI Ir Ro 85° Jt Pl Sm Silt sn 20° Jt Pl DI 20° Jt Pl Sm Silt sn 10° Jt Pl Sm Silt sn Cz 85° Jt Pl Sm Silt sn DI	
	39.1	15.0																		
	38.1	16.0																		
	37.1	17.0																		
	36.1	18.0																		
	35.1	19.0																		
	34.1	20.0																		

Notes:



BOREHOLE LOG

ROCK CORE FORMAT

BH17-EBC-2

Sheet 4 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear Rig Type/ Mounting: MiniSonic Rig Bearing: N/A Date Logged: 9/24/2017

Driller: Brent McAndrew Hole Diameter (mm): 100 mm Plunge: Vertical Date Checked: 1/26/2018

Easting: 503,790.9 m

Northing: 7,974,895.2 m

Surface Elevation: 54.05 m

Bottom Elevation: 32.21 m

Total Depth: 21.8 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Geological Unit	Rock Description ROCK TYPE; Grain size, texture and fabric, colour, general defect conditions, minor constituents.	Weathering/ Cementation	Estimated Strength	Is ₍₅₀₎ [UCS] MPa	Defect Spacing mm	RQD %	
	33.1	21.0					Bedrock, Granitic Gneiss, reddish pink, hard to very hard. Fractures and joints filled with silty sand and clay. <i>(Continued)</i>						
	32.1	22.0					To Target Depth. Drillhole BH17-EBC-2 terminated at 21.8m.						
	31.1	23.0											
	30.1	24.0											
	29.1	25.0											
	28.1	26.0											
	27.1	27.0											
	26.1	28.0											
	25.1	29.0											
	24.1	30.0											

Notes:



BOREHOLE REPORT

BH17-M008-R

Sheet 1 of 4

Client: B.I.M**Project No.:** H353004**Project:** Mary River Expansion Study Stage 2**Datum:** NAD 83**Location:** Rail Indexer Foundation**Platform:** Ground**Contractor:** Boart Longyear**Rig Type/ Mounting:** MiniSonic Rig**Date Logged:** 9/17/2017**Driller:** Brent McAndrew**Hole Diameter (mm):** 100 mm**Date Reviewed:** 1/26/2018**Easting:** 503,772.0 m**Northing:** 7,974,960.0 m**Surface Elevation:** 52.00 m**Bottom Elevation:** 30.01 m**Total Depth:** 22.0 m**Logged By:** R.S**Reviewed By:** G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						NO SAMPLES TAKEN IN OVERBURDEN. Advanced and sonic tube to refusal to begin diamond coring bedrock.				0 25 50							
	51.0	1.0															
	50.0	2.0															
	49.0	3.0															
	48.0	4.0															
	47.0	5.0															
	46.0	6.0															
	45.0	7.0															
	44.0	8.0															
	43.0	9.0															
	42.0	10.0															

Notes: Redrill of BH16-M008. Elevation is approximate.



BOREHOLE REPORT

BH17-M008-R

Sheet 2 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 9/17/2017

Driller: Brent McAndrew

Hole Diameter (mm): 100 mm

Date Reviewed: 1/26/2018

Easting: 503,772.0 m

Northing: 7,974,960.0 m

Surface Elevation: 52.00 m

Bottom Elevation: 30.01 m

Total Depth: 22.0 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
	41.0	11.0				NO SAMPLES TAKEN IN OVERBURDEN. Advanced and sonic tube to refusal to begin diamond coring bedrock. (Continued)				0 25 50							
	40.0	12.0															
	39.0	13.0															
	38.0	14.0															
	37.0	15.0															
	36.0	16.0															
	35.0	17.0															
	34.0	18.0				Start of Coring at 17.4m. Continued on Rock Core Log sheet.											
	33.0	19.0															
	32.0	20.0															

Notes: Redrill of BH16-M008. Elevation is approximate.



BOREHOLE LOG

ROCK CORE FORMAT

BH17-M008-R

Sheet 3 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear **Rig Type/ Mounting:** MiniSonic Rig **Bearing:** N/A **Date Logged:** 9/17/2017

Driller: Brent McAndrew **Hole Diameter (mm):** 100 mm **Plunge:** Vertical **Date Checked:** 1/26/2018

Easting: 503,772.0 m

Northing: 7,974,960.0 m

Surface Elevation: 52.00 m

Bottom Elevation: 30.01 m

Total Depth: 22.0 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Geological Unit	Rock Description ROCK TYPE; Grain size, texture and fabric, colour, general defect conditions, minor constituents.	Weathering/ Cementation	Estimated Strength	Is ₍₅₀₎ [UCS] MPa	Defect Spacing mm [100]	RQD %	
	41.0	11.0											
	40.0	12.0											
	39.0	13.0											
	38.0	14.0											
	37.0	15.0											
	36.0	16.0											
	35.0	17.0											

Resuming in Rock Core Format 17.4m.

Bedrock, Granitic Gneiss, reddish pink, hard to very hard. Fractures and joints filled with silty sand and clay.

Fz

0

10" DI Ir Ro
10" Jt Ir Sm Clay infill 40mm sn
DI
DI
Fz
10" Jt Pl Sm Silt sn

Notes: Redrill of BH16-M008. Elevation is approximate.



BOREHOLE LOG

ROCK CORE FORMAT

BH17-M008-R

Sheet 4 of 4

Client: B.I.M

Project No.: H353004

Project: Mary River Expansion Study Stage 2

Datum: NAD 83

Location: Rail Indexer Foundation

Platform: Ground

Contractor: Boart Longyear **Rig Type/ Mounting:** MiniSonic Rig **Bearing:** N/A **Date Logged:** 9/17/2017

Driller: Brent McAndrew **Hole Diameter (mm):** 100 mm **Plunge:** Vertical **Date Checked:** 1/26/2018

Easting: 503,772.0 m

Northing: 7,974,960.0 m

Surface Elevation: 52.00 m

Bottom Elevation: 30.01 m

Total Depth: 22.0 m

Logged By: R.S

Reviewed By: G.Q

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Geological Unit	Rock Description ROCK TYPE; Grain size, texture and fabric, colour, general defect conditions, minor constituents.	Weathering/ Cementation	Estimated Strength						Is ₍₅₀₎ [UCS] MPa	Defect Spacing mm				RQD %			
									EH	VH	H	M	L	VL		EL	2000	600	200			100	
	31.0	21.0					Bedrock, Granitic Gneiss, reddish pink, hard to very hard. Fractures and joints filled with silty sand and clay. (Continued)								57.9						64	10° DI Ir Ro 10° DI Ir Ro 10° DI Ir Ro 10° DI Ir Ro 30° Jt Pl Sm Silt sn 10° DI Ir Ro 10° DI Ir Ro 10° Jt Cu Sm Silt sn 45° DI Ir Ro 0° DI Ir Ro 10° Jt Ir Ro Silt sn 50° Jt Ir Ro Silt sn 0° DI Ir Ro 0° Jt Ir Sm Silt sn 10° DI Ir Ro	
	30.0	22.0					To Target Depth. Drillhole BH17-M008-R terminated at 22.0m.																
	29.0	23.0																					
	28.0	24.0																					
	27.0	25.0																					
	26.0	26.0																					
	25.0	27.0																					
	24.0	28.0																					
	23.0	29.0																					
	22.0	30.0																					

Notes: Redrill of BH16-M008. Elevation is approximate.

Appendix A3

Thermal Analyses Methodology

Appendix A3

Thermal Analyses

Two-dimensional finite element modelling, with commercially available software (Temp/W), was used to predict the thermal regime for the tunnel foundation.

The air temperature is based on the mean monthly air temperature from Pond Inlet, NU (1981-2010) extracted from the government of Canada website, see Figure A-3-1.

The global warming effect was taken into account according to the Intergovernmental Panel on Climate Change (IPCC) long term climate change studies. A temperature adjustment was applied considering to global warming for the period spanning from 2010 to 2039 (Hatch 2018).

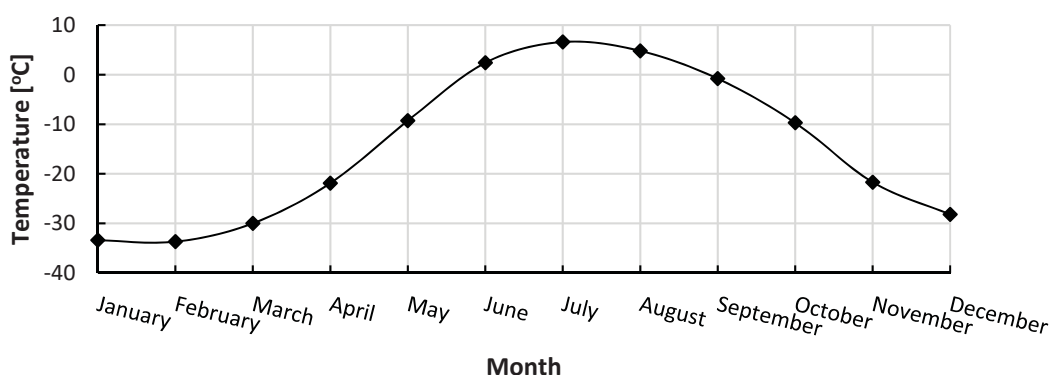


Figure A-3-1: Mean Monthly Temperatures for Pond Inlet, NU (1981-2010)

Surface boundary conditions at the site were obtained based on the n-factors which was used to correlate air temperatures to ground surface temperatures during cold seasons (n_f) and thaw seasons (n_t). Values of n_f and n_t used in the analysis were summarized in Table A-3-1. Typically, n_f is less than 1 considering the impact of snow accumulation/insulation over ground surface during winter while n_t is more than 1 considering the impact of radiation.

Inside the tunnel, the n factor of 1 was used assuming that the ground surface temperature is same as the air temperature. It is noted that in summer the air temperature in the tunnel could be colder than the air temperature outside while in winter, the inside air temperature in the tunnel becomes is likely warmer than the outside air temperature. There is no sufficient data/study to quantify the two opposite effects. As such, this study assumed that the air temperature in tunnel is same.

The available thermistor data from the Mary River site (Hatch, 2012) indicate that ground temperature reaches equilibrium (at -10°C) below 15m depth, thus the bottom boundary was assumed to be 15m below the ground surface, with a constant temperature of -10°C .

The construction of the tunnel foundation is set in April, 2019.

The results are shown in the figures in this appendix.

Table A-3-1: N-factors to be Used in Modelling

Material	N – factors	
	Freezing (n_f)	Thawing (n_t)
Native Sand	0.7	1.2
Native Silt	0.5	1.2
Rockfill / Granular Backfill	0.8	1.5
Tunnel Inside Boundary	1	1

Appendix A4

Settlement Analyses Methodology

Appendix A4

Settlement Analyses

Two-dimensional finite element modelling, with commercially available software (Sigma/W), was used to predict the displacement.

Figure A-4-1 and Table A-4-2 shows the engineering parameters for unfrozen soil, frozen silt and frozen till used in the analyses.

In the model, the creep deformation was modeled using a long-term strength envelope and equivalent long-term deformation modulus (see details in Hatch 2018).

For the soil beyond structures/facilities, the following simplified soil profile was used as per the warmest envelope from the thermistor monitoring data (see the figure below).

- 0 m to 3 m depth: Soil in Active Zone*
- 3 m to 7 m depth: Frozen Soil (above -7°C)
- Below 7 m depth: Frozen Soil (below -7°C)

Note: * The properties of the unfrozen soil was used for the soil between 2 m to 3 m depth as a conservative assumption.

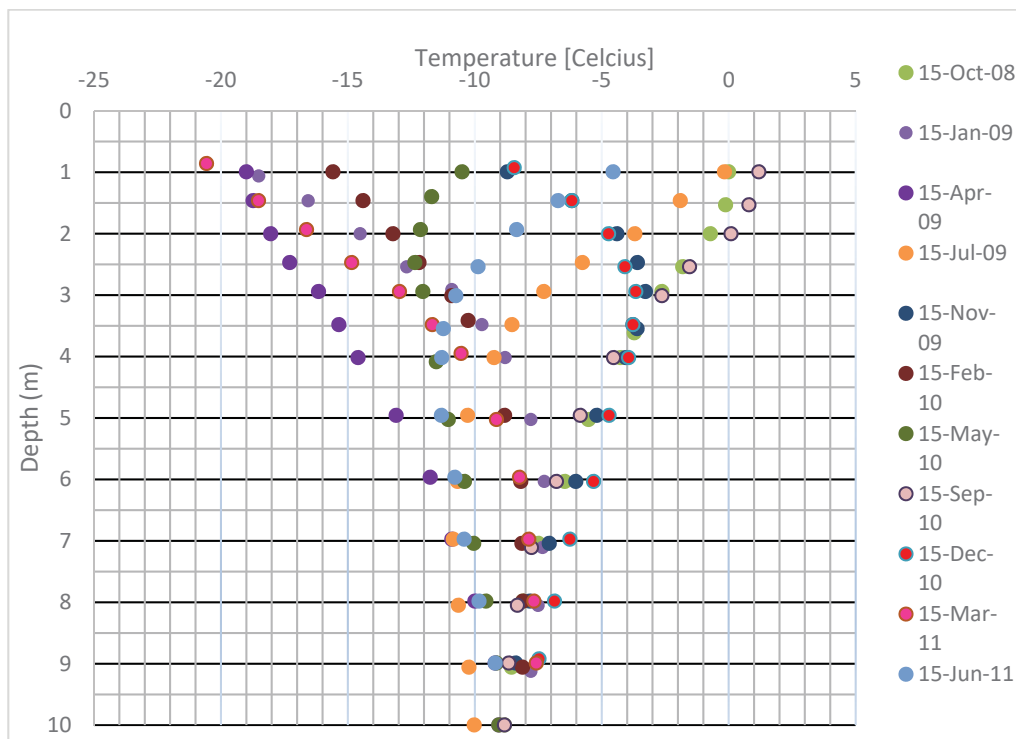


Figure: A-1: Temperature Profiles containing Numerical and Recorded Data Overlain
(Thermistor data from BH2007-10, reported by Knight Piesold, 2008)

Table A-4-1: General Design Parameters

Materials	Elastic Young's Modulus	Poisson's Ratio	Unit Weight kN/m ³	Strength Parameters	
	Es, (MPa)			c' (kPa)	φ' (Degrees)
Ore	30	0.33	26	0	40°
Engineered Fill (compacted crushed rockfill)	70	0.33	22	0	40°
Rockfill	70	0.33	22	0	40°
Native Silt	8 (unfrozen condition)	0.33	18	0	30°
Native Sand	15 (unfrozen condition)	0.33	18	0	32°

Table A-4-2: Design Parameters for Frozen Silty Permafrost

Temperature	Long-term Deformation Modulus	Poisson's Ratio	Unit Weight kN/m ³	Strength Parameters For Creep Analyses (20-year design life)	
	Ec, (MPa)			c' _{LT} (kPa)	φ' _{LT}
Above - 7° C	22	0.33	18	0	30°
Below -7° C	44	0.33	18	0	30°

Note: The underlying till material is considered very stiff in its hard frozen state (< - 7°C) with a high deformation modulus of 1,000 MPa.

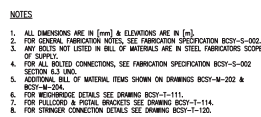
Table A-4-3: Design Parameters for Frozen Sandy Permafrost

Temperature	Long-term Deformation Modulus	Poisson's Ratio	Unit Weight kN/m ³	Strength Parameters For Creep Analyses (20-year design life)	
	Ec, (MPa)			c' _{LT} (kPa)	φ' _{LT}
Above - 7° C	80	0.33	18	0	32°
Below -7° C	160	0.33	18	0	32°

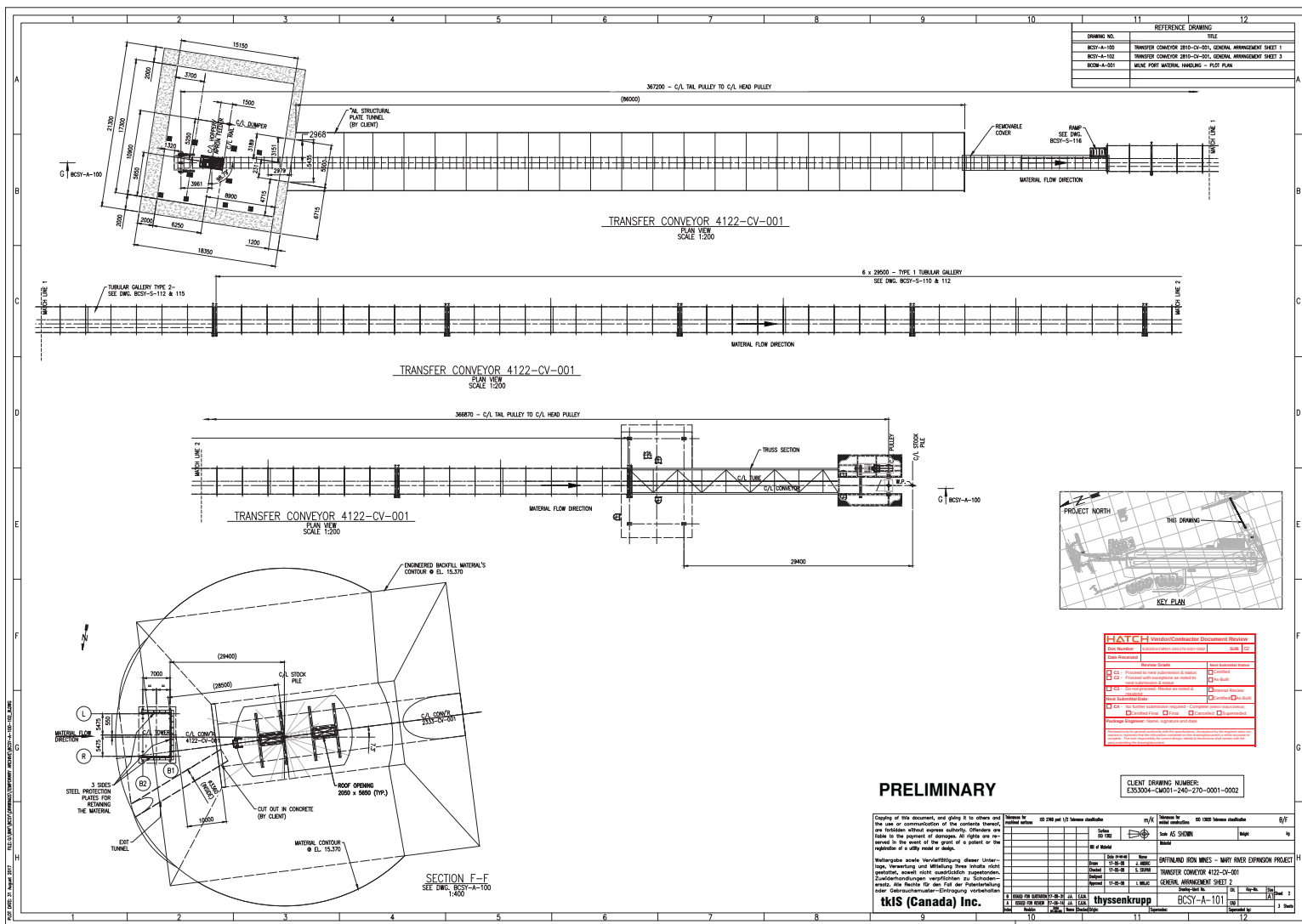
Note: The underlying till material is considered very stiff in its hard frozen state (< - 7°C) with a high deformation modulus of 1,000 MPa.

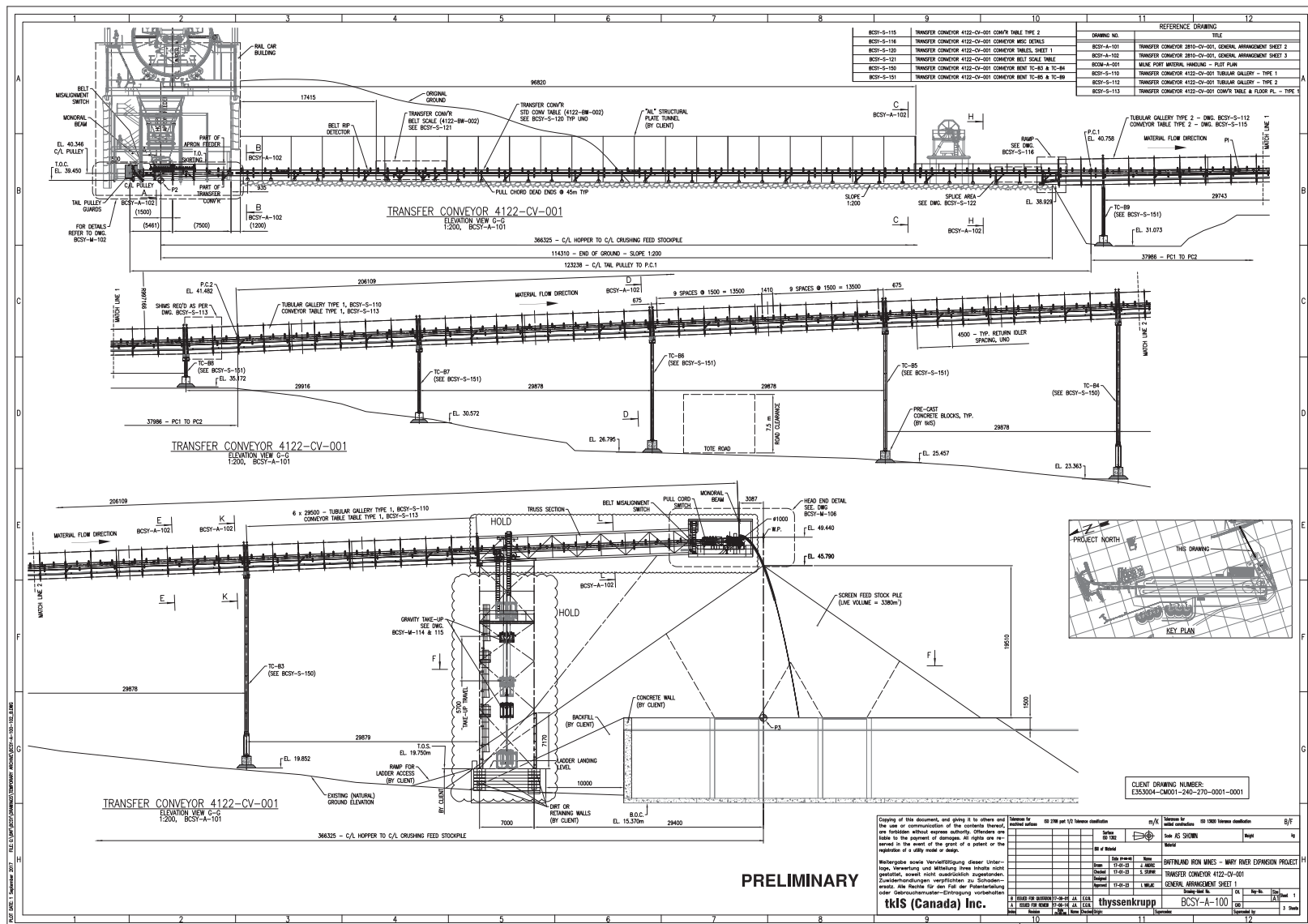
Appendix B1

Stockpile Reclaim Tunnel Drawings



	11	12
	REFERENCE DRAWING	
DRAWING NO.	TITLE	
BCSY-A-100	TRANSFER CONVEYOR 2810-CV-001, GENERAL ARRANGEMENT SHEET 1	
BCSY-A-102	TRANSFER CONVEYOR 2810-CV-001, GENERAL ARRANGEMENT SHEET 3	
BCOM-A-001	MINE PORT MATERIAL HANDLING - PLOT PLAN	





Request for Information - to Contractor

RFI Number: 0045	Subject: Foundation Loads and Design Criteria			Revision: 0
Originator: Deena Naidoo	Package CM001	Discipline CSA	Project: H353004	
Date Submitted: 12 October 2017		Required Response Date 17 October 2017		
Information Required Please provide 1. Design criteria (total and differential settlement requirements) 2. Design loads/pressures 3. Footing sizes/designs For the following areas a. Crusher and crusher services buildings b. Screening building c. Primary Stockpile Tunnel d. Reclaim Tunnel e. Reclaimer Berm f. All piled foundations				
Answer/Response (Use Additional Sheets As Required) See attached response.				
Hatch Project Engineer	Signature  Digitally signed by Naidoo, Deena DN: cn="Naidoo, Deena" Location: Mississauga Reason: I am signing this document Contact Info: +16473837855 Date: 2017.10.12 11:03:48-04'00'		Date: 12/10/2017	
Hatch Area Manager	Signature		Date	
Contractor Representative	Signature  Digitally signed by Laurent Foulonneau DN: cn=Laurent Foulonneau, o=Hatch email=laurent.foulonneau@hatchgroup.com Date: 2017.11.17 18:19:33 -07'00'		Date	

tk IS response to Hatch RFI H353004-CM001-400-465-0045

Crusher and screen buildings

Maximum differential settlement between any two adjacent pontoons: 10 mm.

Maximum total settlement without major rework to equipment: 10 mm

Design loads/pressure: minimum unfactored bearing pressure: 350 kPa per drawing 4853005 under pontoon.

Footing size: See drawing 4853005, BCRU-K-002 and BSCR-K-001

Crusher services building

See tk IS response to Hatch RFI H353004-CM001-400-465-0055

Primary stock pile tunnel;

- Total settlement shall not exceed 20 mm

- Differential settlement of footing along the length of the tunnel: 1/1000

- Differential settlement between footings at any transverse section: 50 mm for the tunnel / 6 mm for the apron feeder structure

- Unfactored bearing pressure: 750 KPa

Footing size: see drawings BCSY-A-200 and BCSY-K-203

Reclaim tunnel

- We do not make a distinction between the primary stock pile tunnel & the reclaim tunnel. Both areas would have the same criteria.

Reclaimer berm

- For total and differential settlement see attached drawing 4935166. Tolerances indicating on these drawings are for installation and operation tolerances.

- For load information and layout please refer to attached drawings 4500001466-B07-0001-001, E353004-CM001-240-272-4006 and E353004-CM001-230-272-4007-0001.

Piled foundation

- Total and differential settlement =0 mm

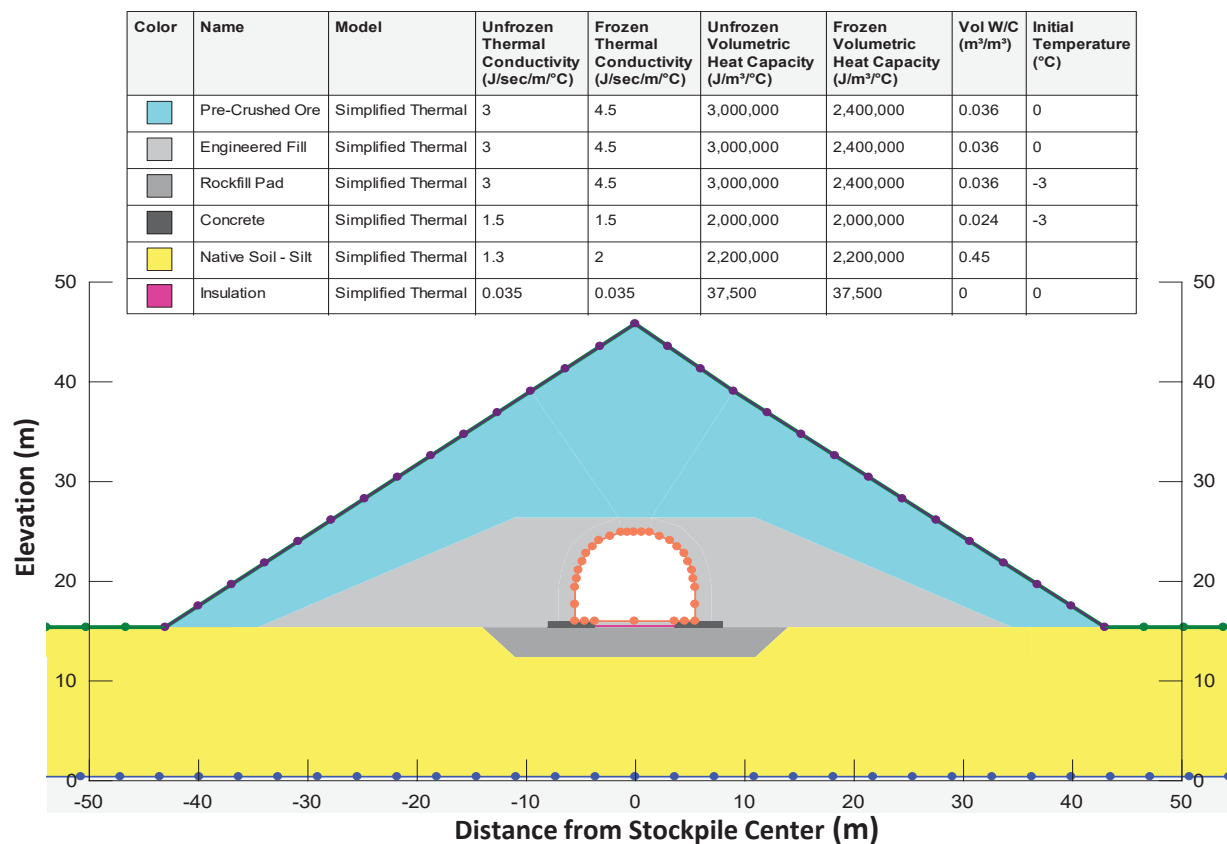
- Capacity adequate for the provided loads. See tk IS foundation load drawings.

- Note that spring constants for each foundation are required to confirm foundation loads.

Appendix B2

Thermal Analyses – Stockpile Reclaim Tunnel

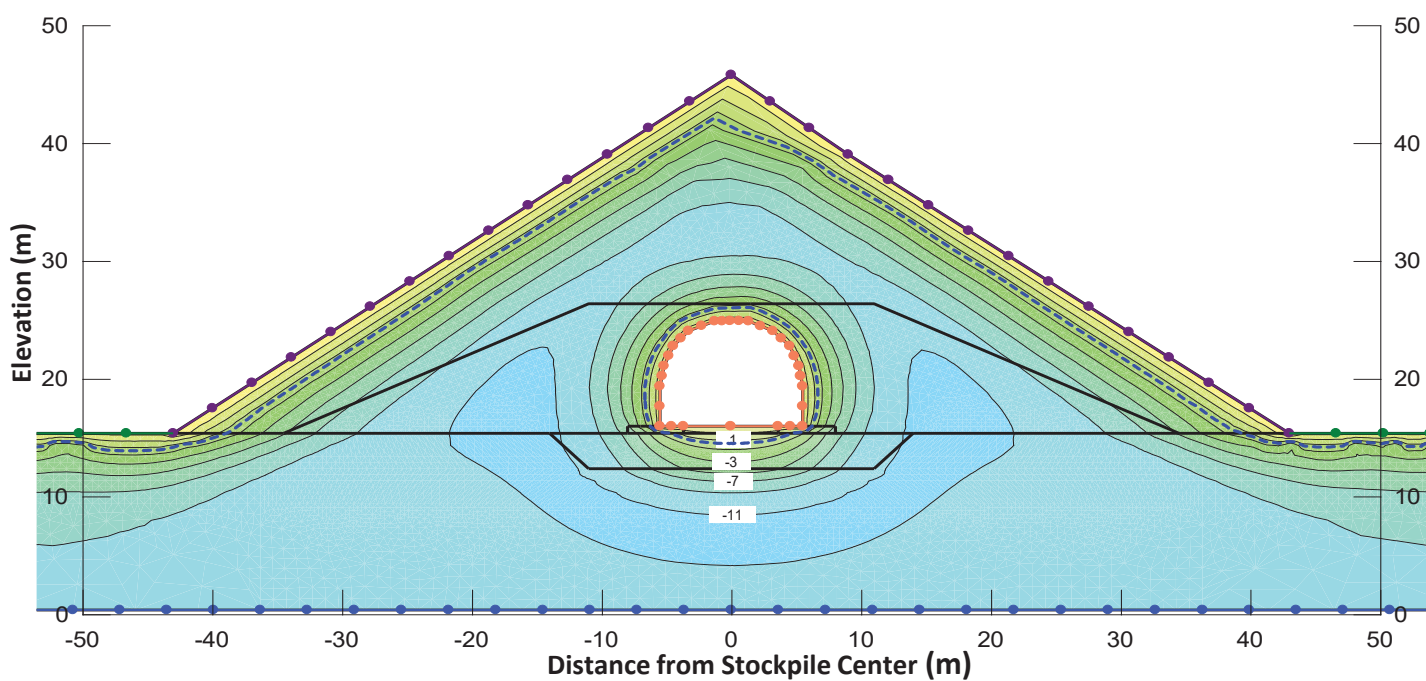
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Job number		353004		Mary River Expansion Project			BIM		
Ref		Stockpile Tunnel		Thermal Model			Milne Inlet Port		
By		Lk	0				28-Feb-18		
Revision		A	28-Feb-18						
								FIGURE B2-1	

Fig B2-1 | 2/28/2018 2:34 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Figure Thermal Model - Stockpile Tunnel.xlsx

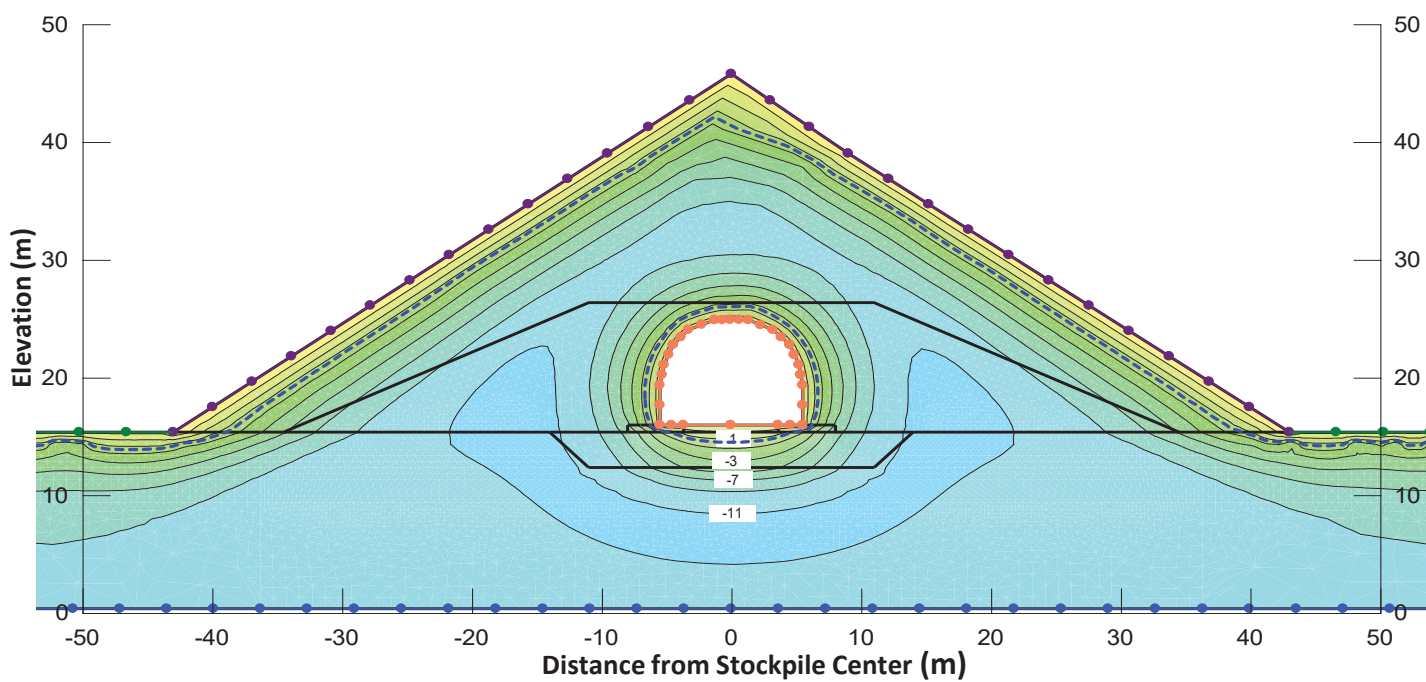
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Job number		353004		Mary River Expansion Project			BIM	
Ref	Stockpile Tunnel			No Insulation Temperature Contour In Summer (2 yr after construction)			Milne Inlet Port	
By	Lk	0	28-Feb-18					
Revision		A	28-Feb-18					
FIGURE B2-2								

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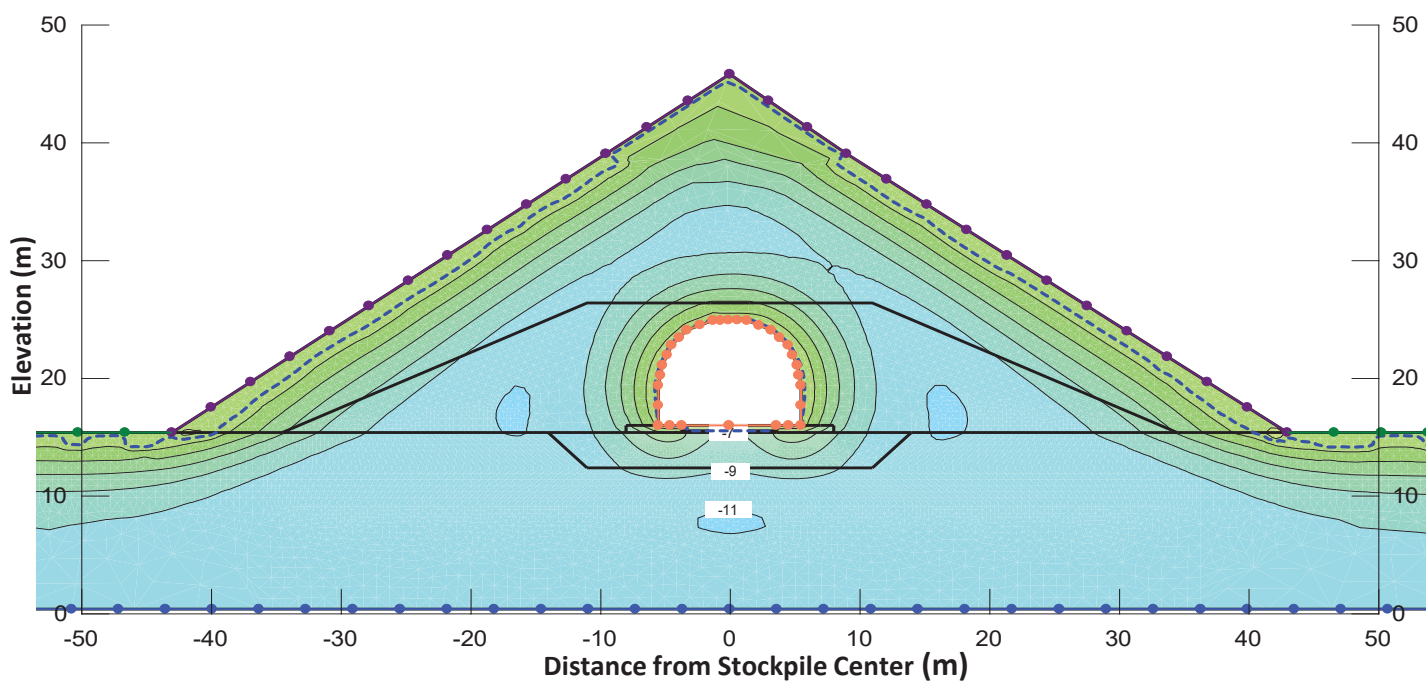
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Job number		353004		Mary River Expansion Project No Insulation Temperature Contour In Summer (20 yr after construction) HATCH		BIM	
Ref	Stockpile Tunnel					Milne Inlet Port	
By	Lk	0	28-Feb-18				
Revision		A	28-Feb-18				

Fig B2-3 | 2/28/2018 2:34 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Figure Thermal Model - Stockpile Tunnel.xlsx

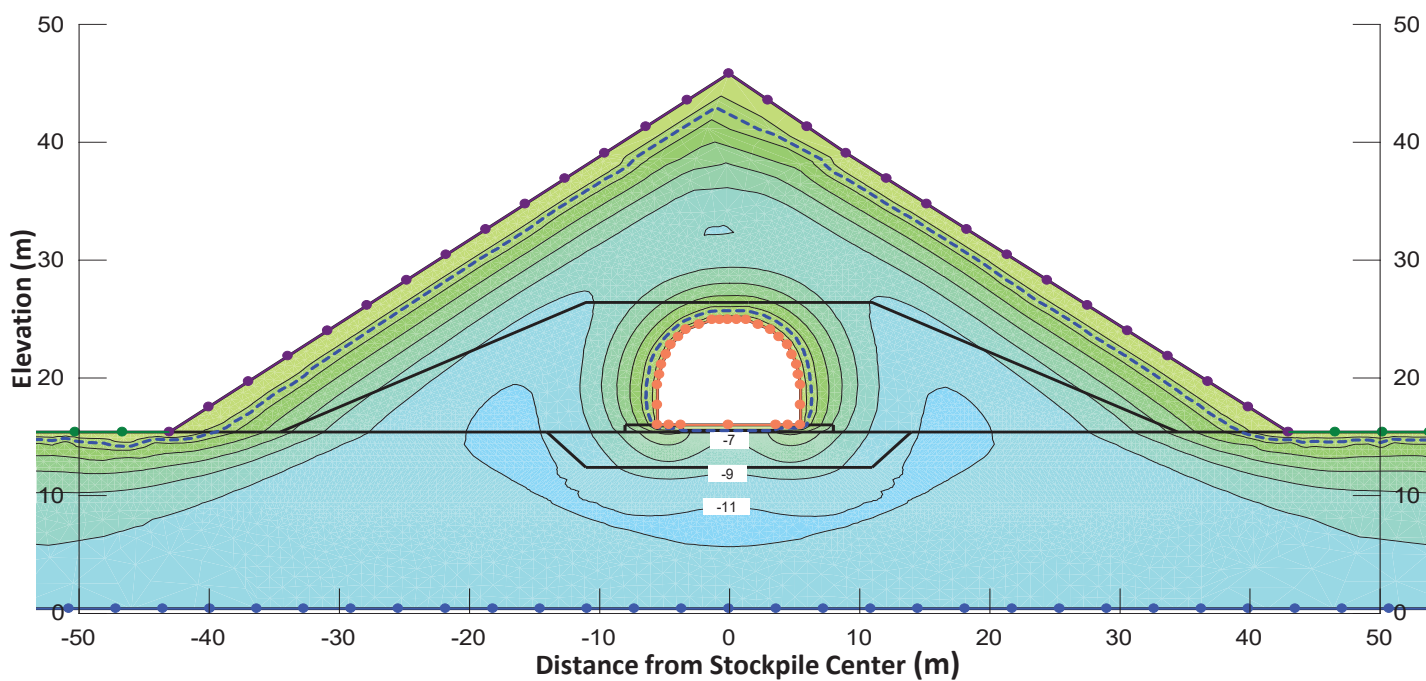
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Job number		353004		Mary River Expansion Project Insulation Temperature Contour In Summer (2 yr after construction) HATCH		BIM	
Ref	Stockpile Tunnel					Milne Inlet Port	
By	Lk	0	28-Feb-18			FIGURE B2-4	
Revision		A	28-Feb-18				

Fig B2-4 | 2/28/2018 2:34 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Mary River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Figure Thermal Model - Stockpile Tunnel.xlsx

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Job number		353004		Mary River Expansion Project			BIM		
Ref	Stockpile Tunnel			Insulation Temperature Contour In Summer (20 yr after construction)			Milne Inlet Port		
By	Lk	0	28-Feb-18						
Revision		A	28-Feb-18						
								FIGURE B2-5	

Fig B2-5 | 2/28/2018 2:34 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Figure Thermal Model - Stockpile Tunnel.xlsx

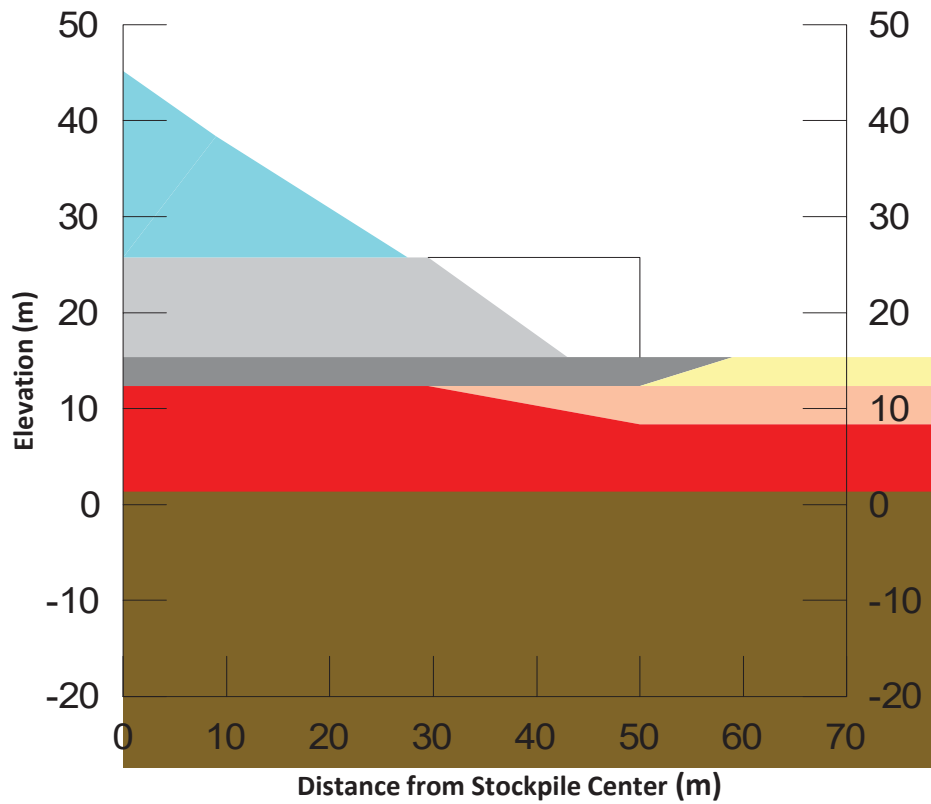
Appendix B3

Settlement Analyses – Stockpile Reclaim Tunnel

Color	Name	Model	Effective Young's Modulus (E') (kPa)	Cohesion' (kPa)	Phi' (°)	Poisson's Ratio	Unit Weight (kN/m³)
	Pre-Crushed Ore	Elastic-Plastic (Effective)	25,000	0	40	0.33	26
	Granular Engineering Fill	Elastic-Plastic (Effective)	70,000	0	40	0.33	22
	Native Silt	Elastic-Plastic (Effective)	7,000	0	30	0.33	18
	Frozen Silt (E=22 mPa)	Elastic-Plastic (Effective)	22,000	0	30	0.33	18
	Frozen Silt (E=44 mPa)	Elastic-Plastic (Effective)	44,000	0	30	0.33	18
	Steel Reinforced Structure	Linear Elastic (Effective)	30,000,000			0.2	20
	Till	Elastic-Plastic (Effective)	1,000,000	0	35	0.33	22
	Concrete	Linear Elastic (Effective)	30,000,000			0.2	24
	Rockfill Foundation	Elastic-Plastic (Effective)	70,000	0	40	0.33	22

Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation
Ref	Stockpile Tunnel			Material Properties	Milne Inlet Port		
By	LK	0	04-Mar-18				
Revision		A	04-Mar-18				
FIGURE B3-1							

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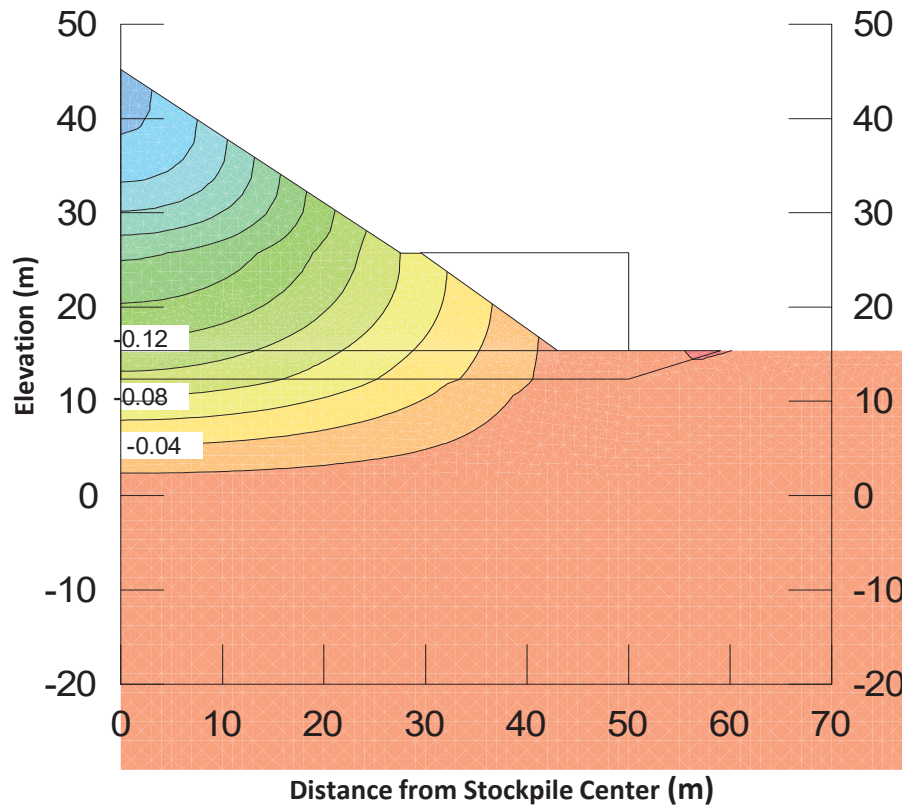


Color	Name
■	Pre-Crushed Ore
■	Granular Engineering Fill
■	Native Silt
■	Frozen Silt (E=22 mPa)
■	Frozen Silt (E=44 mPa)
■	Till
■	Rockfill Foundation

Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation	
Ref	Stockpile Tunnel			Case 1			Milne Inlet Port	
By	LK	0	04-Mar-18					
Revision		A	04-Mar-18				FIGURE B3-1A	

Fig B3-1A | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx

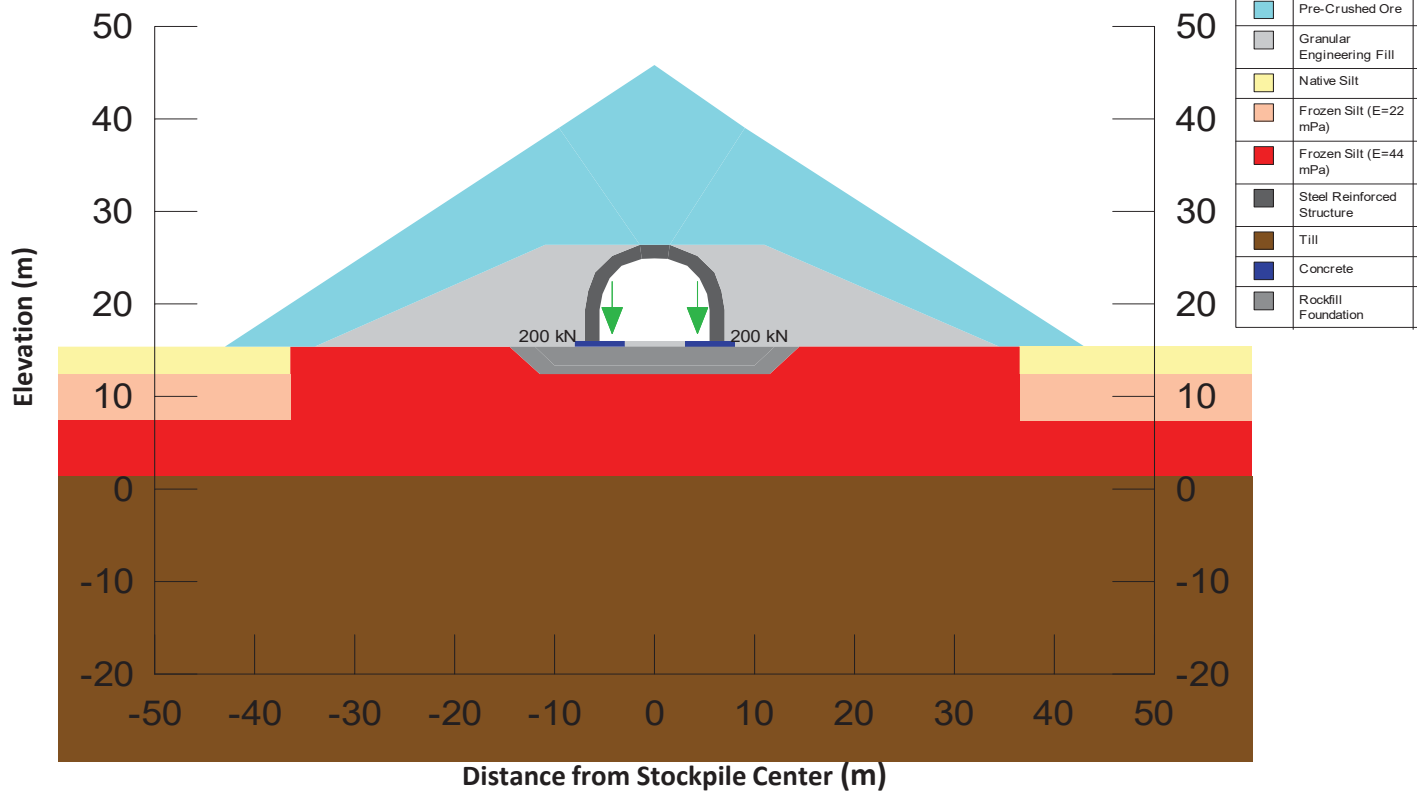
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Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation	
Ref	Stockpile Tunnel			Case 1 - Results			Milne Inlet Port	
By	LK	0	04-Mar-18					
Revision		A	04-Mar-18				FIGURE B3-1B	

Fig B3-1B | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx

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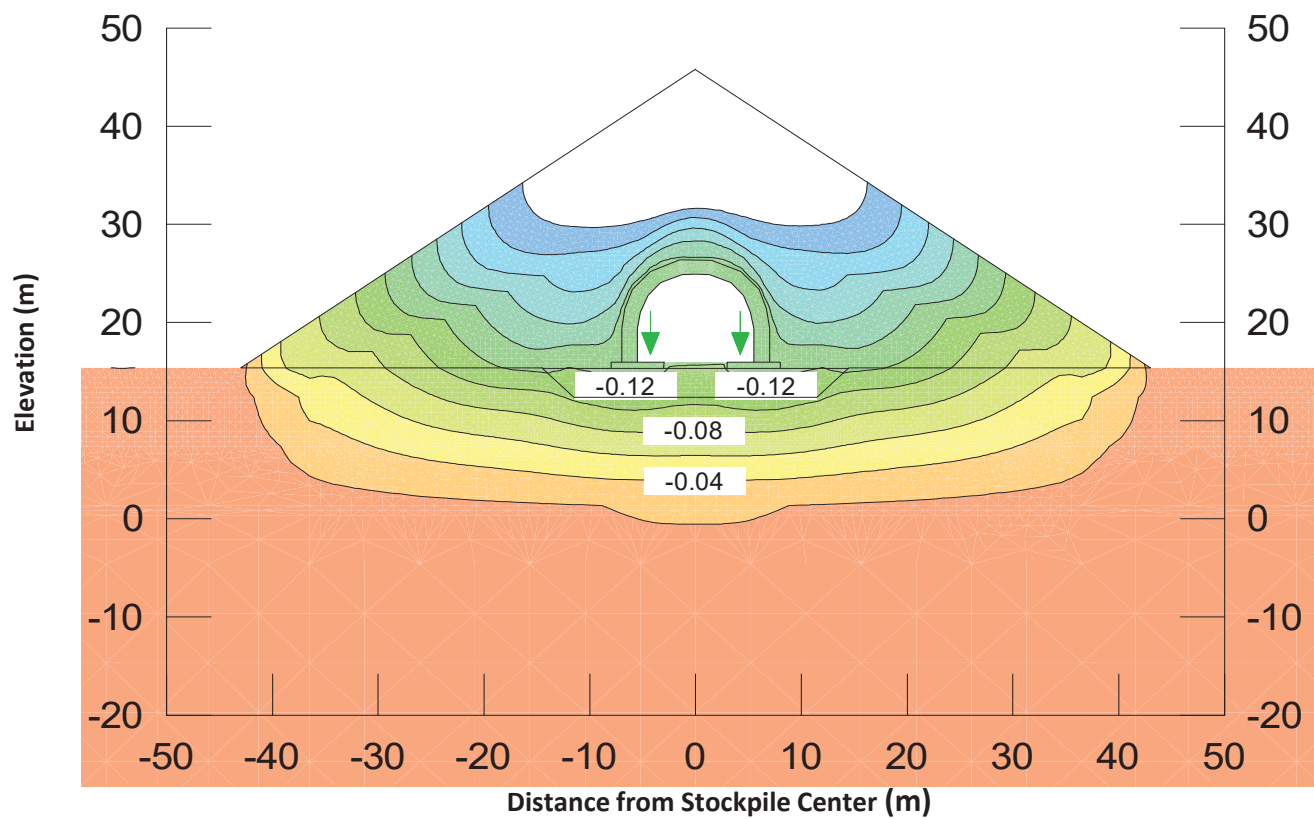


Note: The load of 200 kN was estimated from the maximum of the average loads of each steel frame segment (Reference: Drawing E3530004-CM001-2200272-0015).

Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation	
Ref	Stockpile Tunnel			Case 2			Milne Inlet Port	
By	LK	0	04-Mar-18					
Revision		A	04-Mar-18					
FIGURE B3-2A								

Fig B3-2A | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx

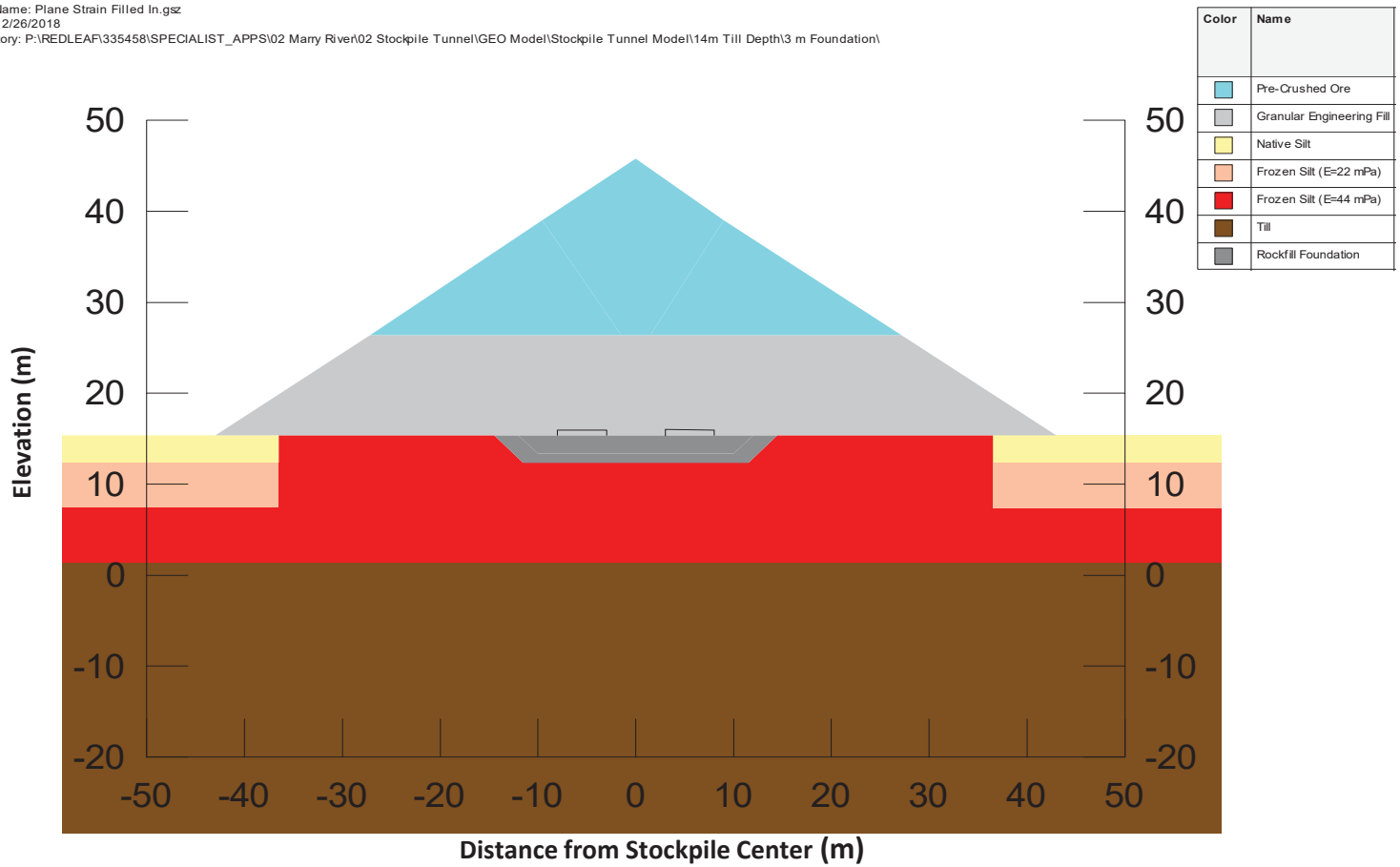
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Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation
Ref	Stockpile Tunnel			Case 2 - Results			Milne Inlet Port
By	LK	0	04-Mar-18				
Revision		A	04-Mar-18				
							FIGURE B3-2B

Fig B3-2B | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Mary River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx

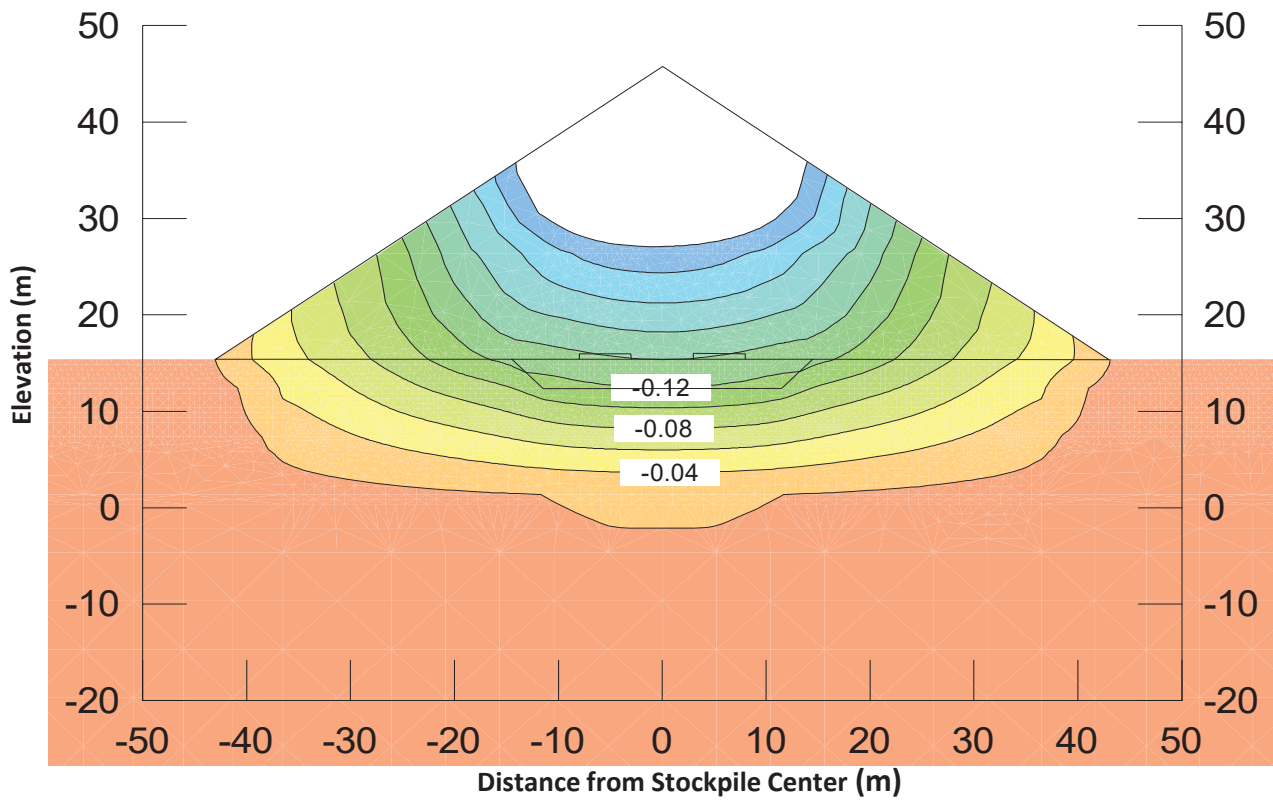
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Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation	
Ref		Stockpile Tunnel		Case 3			Milne Inlet Port	
By		LK 0 04-Mar-18						
Revision		A 04-Mar-18					FIGURE B3-3A	

Fig B3-3A | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Mary River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx

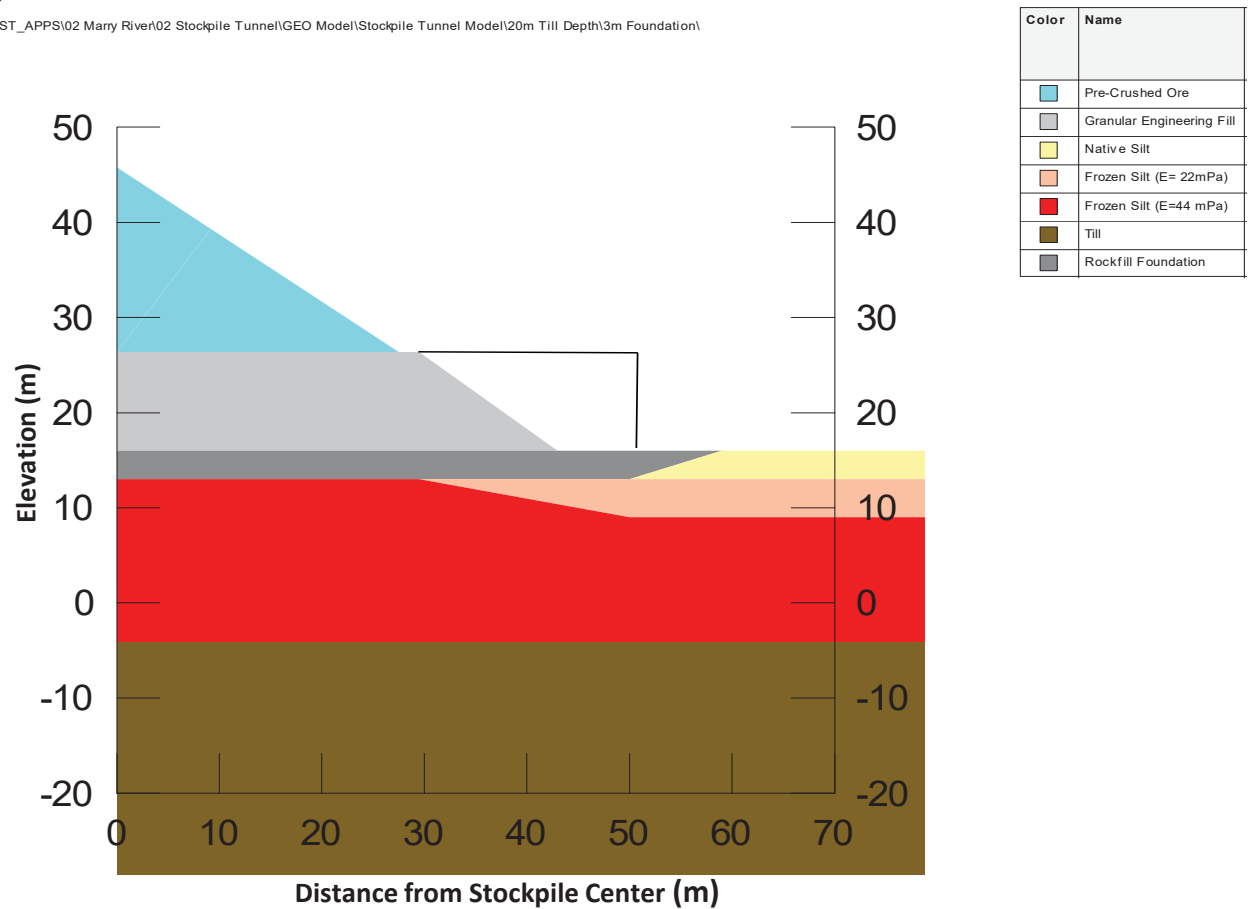
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Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation	
Ref	Stockpile Tunnel			Case 3 - Results			Milne Inlet Port	
By	LK	0	04-Mar-18					
Revision		A	04-Mar-18				FIGURE B3-3B	

Fig B3-3B | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Mary River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx

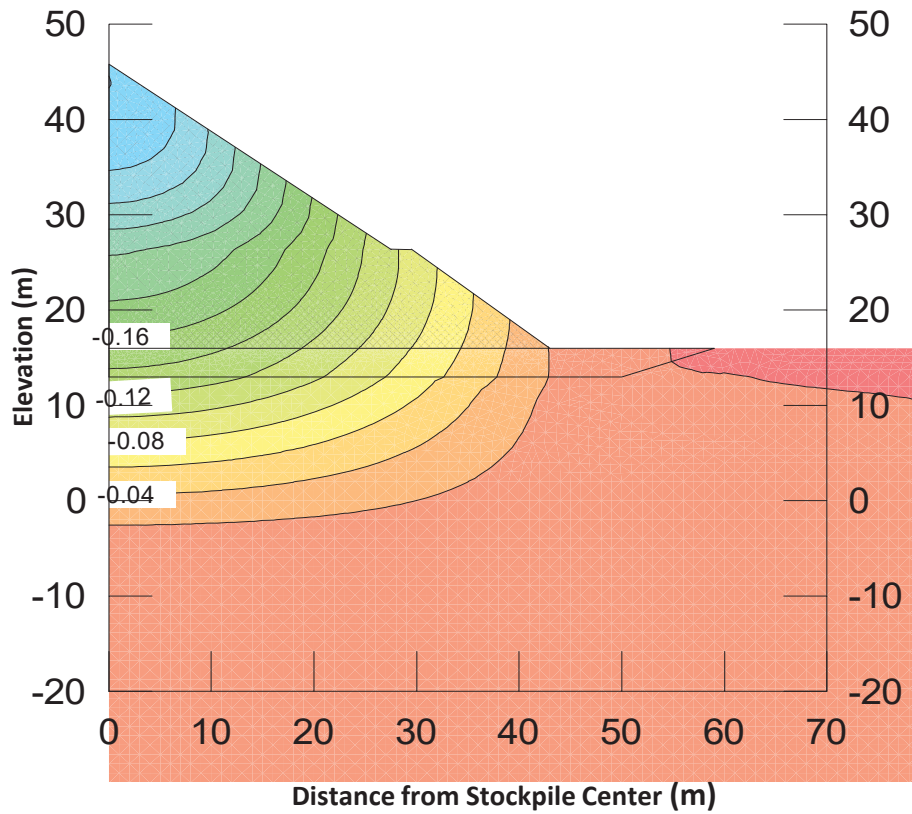
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Job number		353004		Mary River Expansion Project			Baffinland Iron Mines Corporation			
Ref		Stockpile Tunnel		Case 4			Milne Inlet Port			
By		LK	0				04-Mar-18		FIGURE B3-4A	
Revision		A					04-Mar-18			

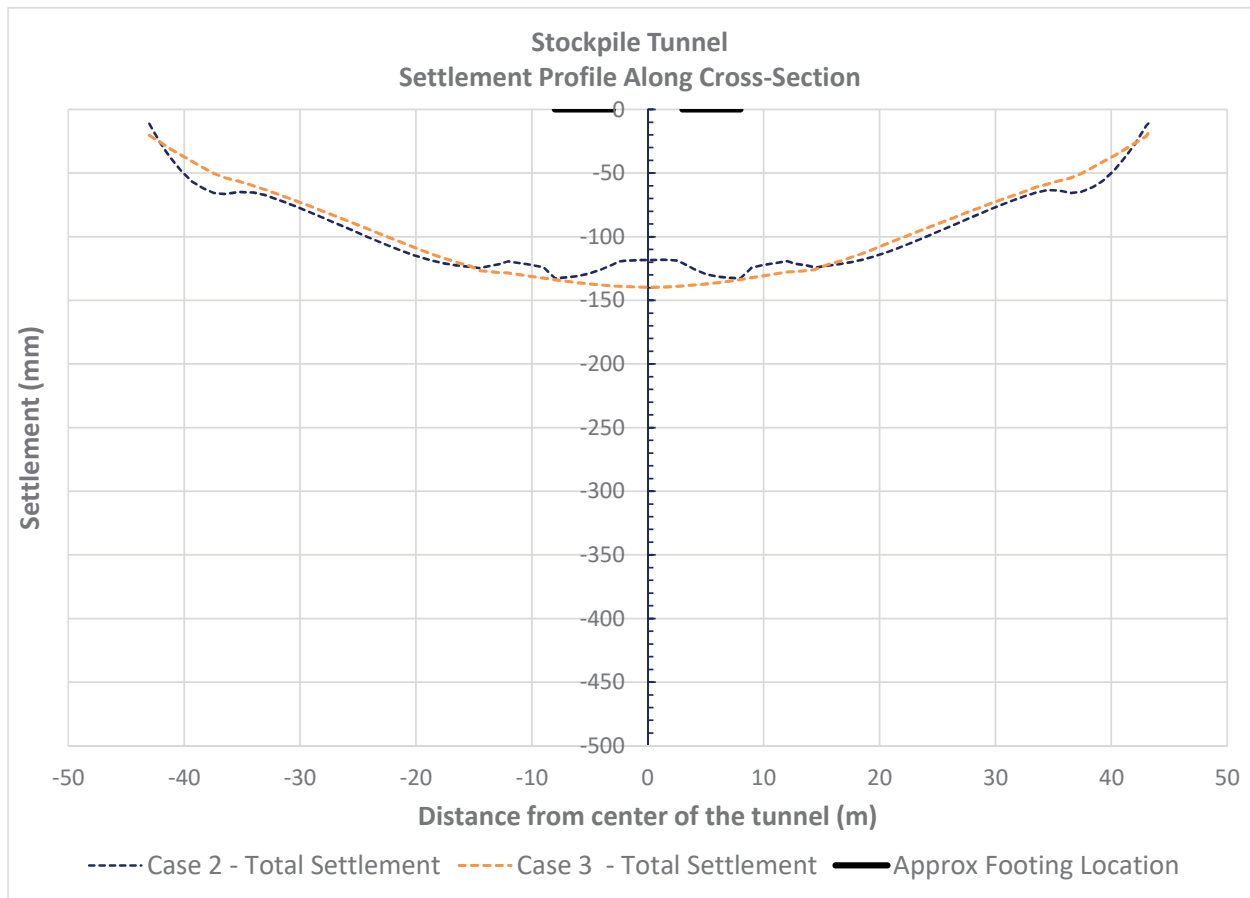
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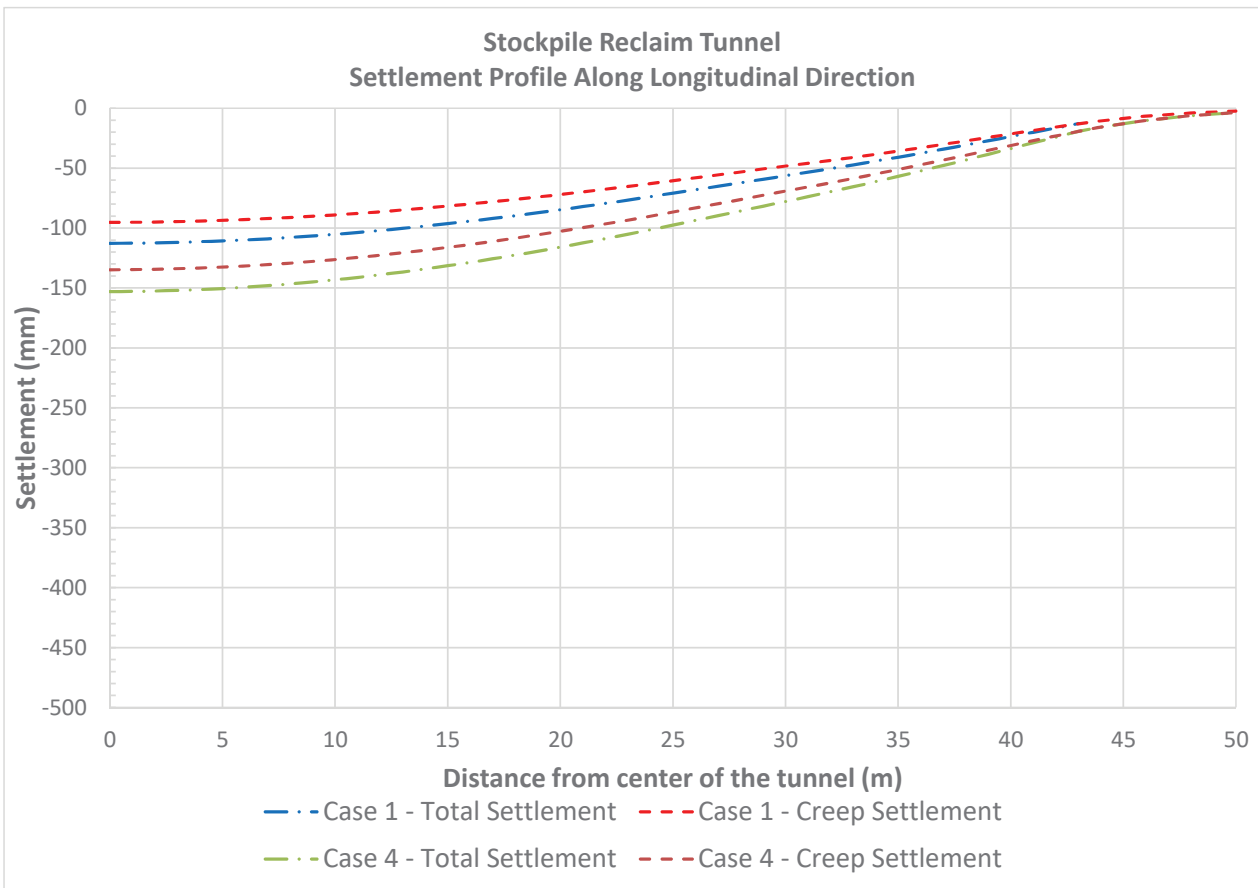
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Ref		Stockpile Tunnel		Case 4 - Results			Milne Inlet Port
By	LK	0	04-Mar-18				
Revision		A	04-Mar-18				FIGURE B3-4B

Fig B3-4B | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Mary River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx



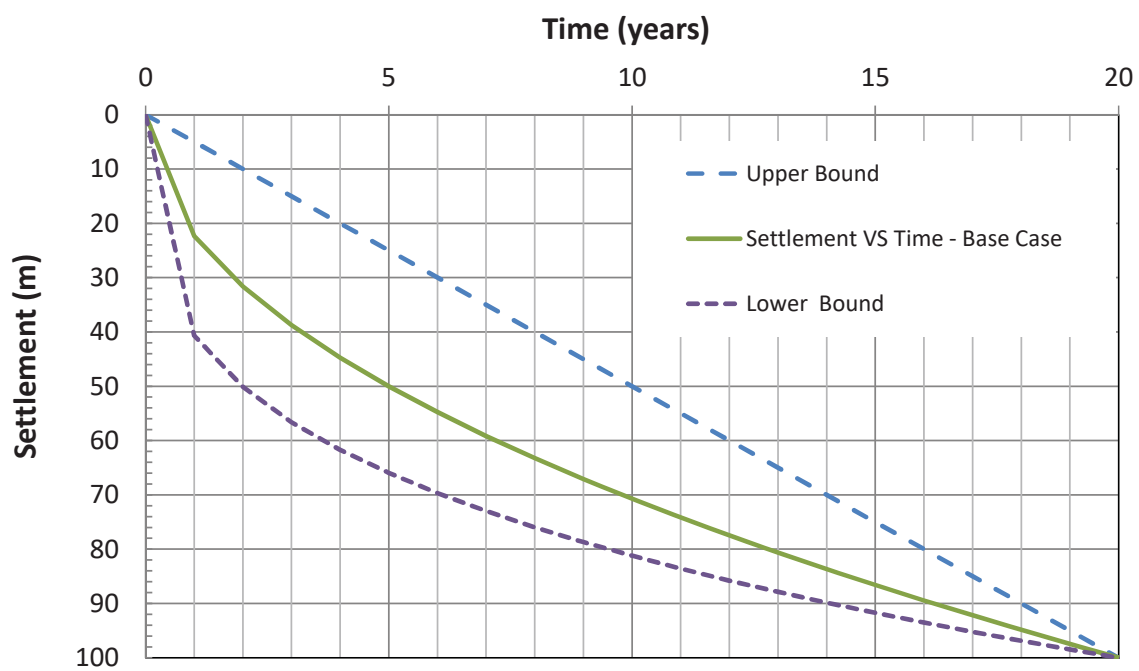
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Ref		Stockpile Tunnel		Comparison of Case 2 and Case 3			Milne Inlet Port	
By		LK	0				04-Mar-18	
Revision		A	04-Mar-18					
FIGURE B3-5								

Fig B3-5 | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Mary River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx



Job number		353004		Mary River Expansion Project Comparison of Case 1 (14 m silt) and Case 4 (20 m silt) HATCH		Baffinland Iron Mines Corporation	
Ref	Stockpile Tunnel					Milne Inlet Port	
By	LK	0	04-Mar-18				
Revision		A	04-Mar-18				

Fig B3-6 | 3/4/2018 10:22 AM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Mary River\02 Stockpile Tunnel\GEO Model\Stockpile Tunnel Model\Summary\Footing Settlement Rev 4.xlsx

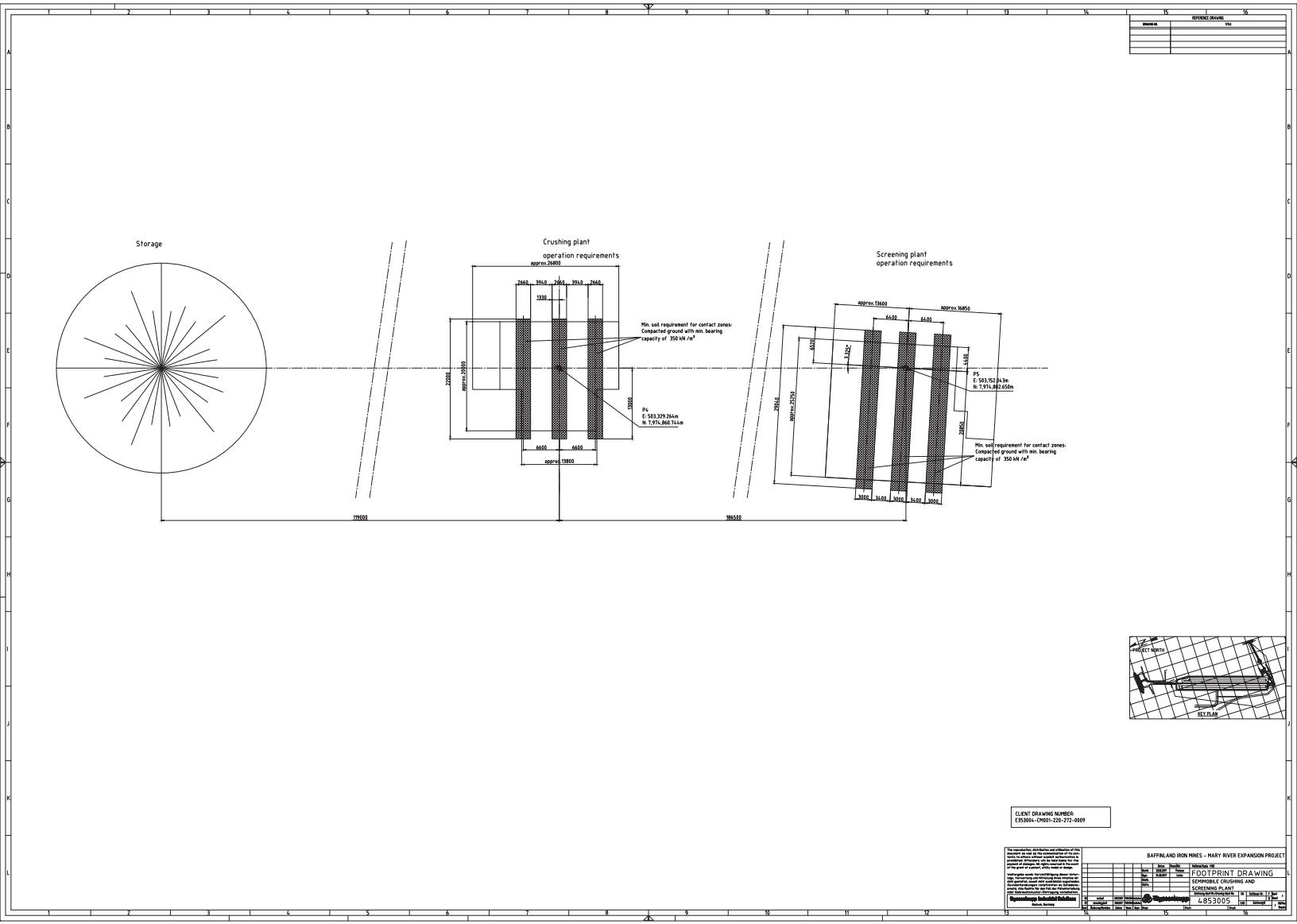


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Ref	Stockpile Tunnel			Creep Settlement Versus Time	Milne Inlet Port		
By	LK	0	04-Mar-18				
Revision		A	04-Mar-18		FIGURE B3-7		

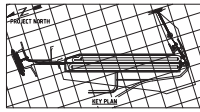
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Appendix C1

Crushing/Screening Plant Drawings

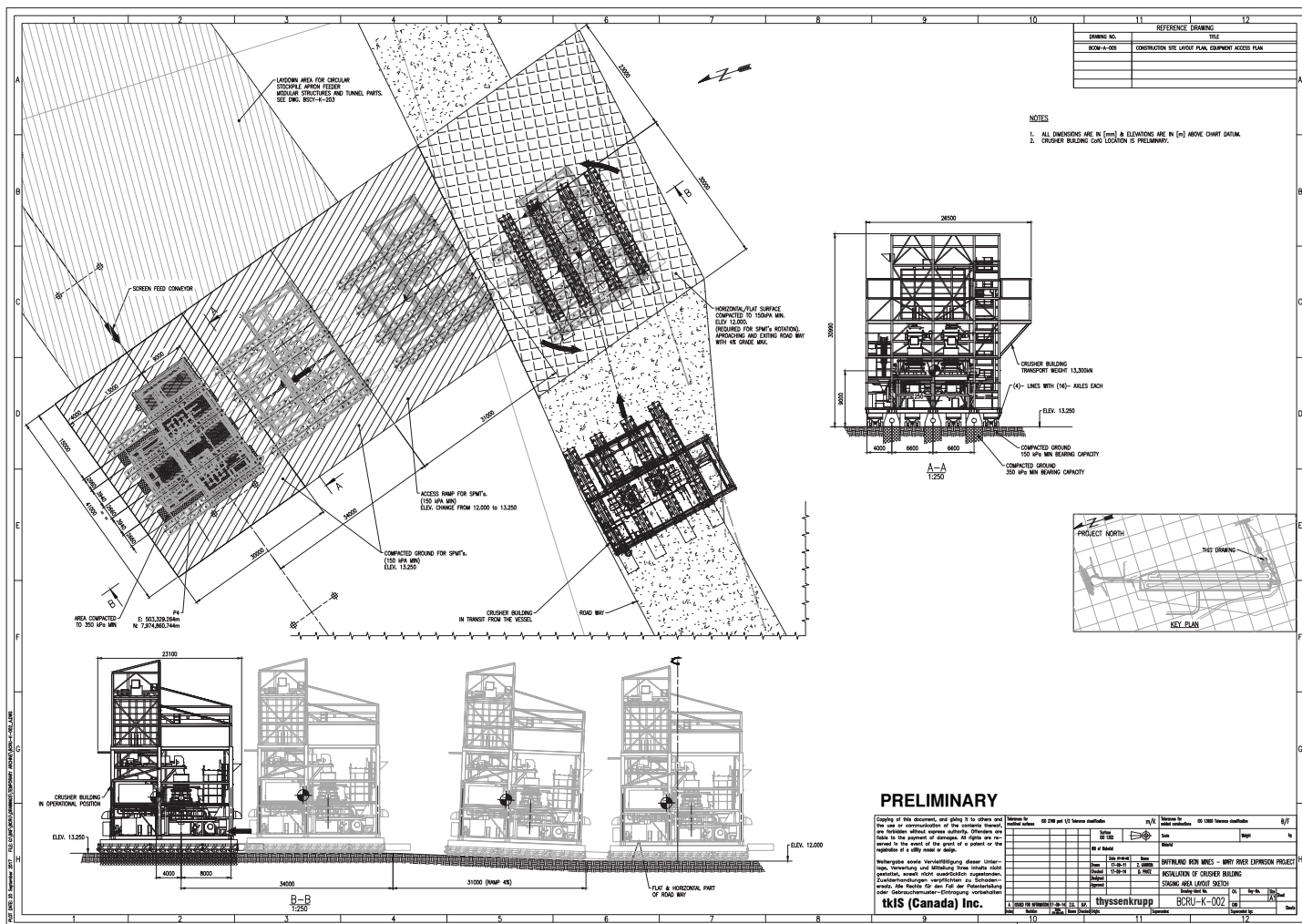


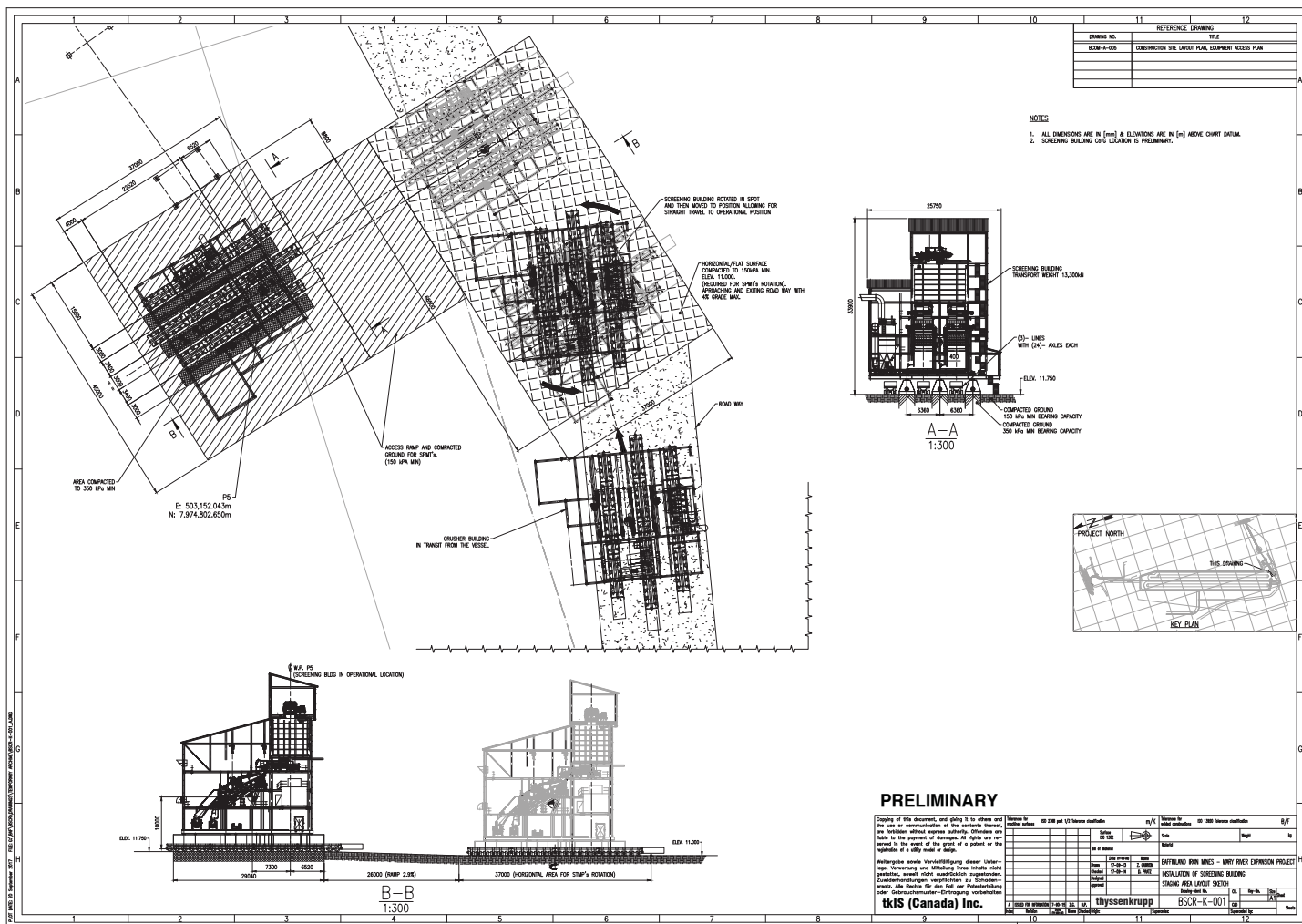
Sheet No.	Sheet Description
1	Crushing plant
2	Screening plant
3	Storage

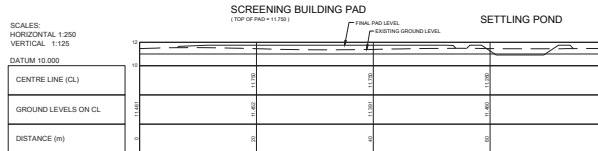


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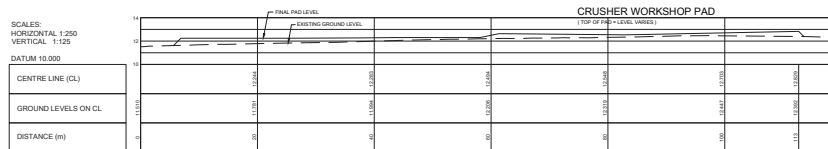
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Project Number	E353004-CH001-220-272-0009
Project Stage	FOOTPRINT DRAWING
Project Location	CRUSHING PLANT AND SCREENING PLANT
Project Date	4/8/2005
Project Author	4/8/2005
Project Reviewer	4/8/2005
Project Approver	4/8/2005



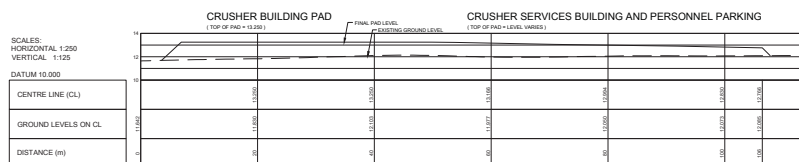




CROSS SECTION A - A

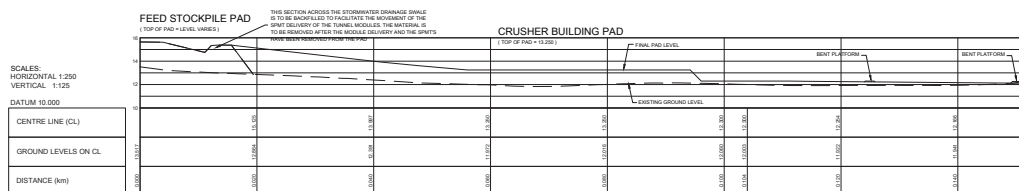


CROSS SECTION B - B

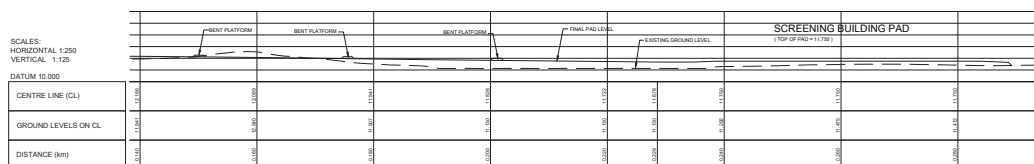


NOTE: FOR PAD LAYERWORKS REFER TO TYPICAL SECTIONS SHOWN FOR CUT / FILL AND UNDER BUILDINGS ON DRG No. H353004-00000-221-294-0308-0301

CROSS SECTION C - C



CROSS SECTION D - D



CROSS SECTION D - D (CONTINUED)

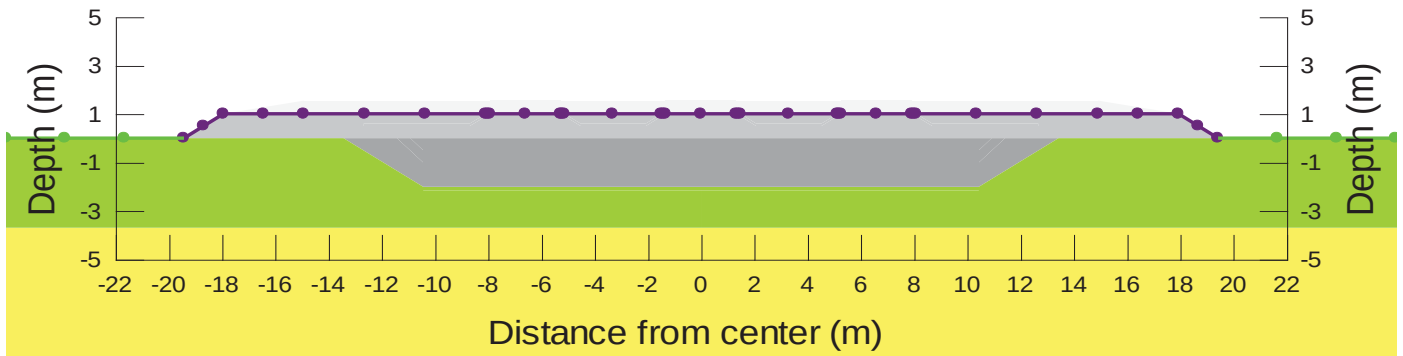
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Appendix C2

Thermal Analyses – Crushing/Screening Plant

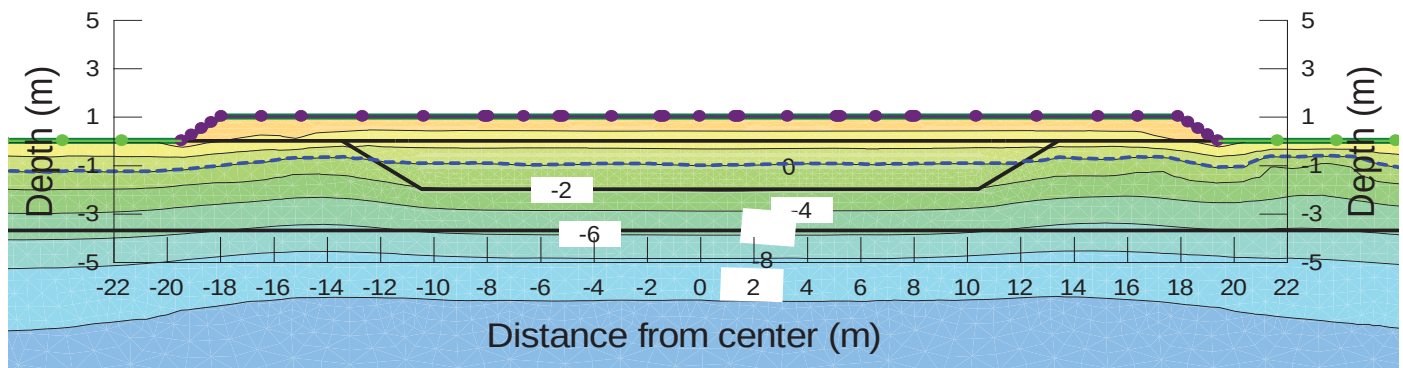
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 Date: 3/28/2018
 Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\

Color	Name	Model	Unfrozen Thermal Conductivity (J/sec/m/°C)	Frozen Thermal Conductivity (J/sec/m/°C)	Unfrozen Volumetric Heat Capacity (J/m ³ /°C)	Frozen Volumetric Heat Capacity (J/m ³ /°C)	Vol W/C (m ³ /m ³)	Initial Temperature (°C)
	Rockfill above ground	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	0
	Rockfill Pad	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	-3
	Silt	Simplified Thermal	1.3	2	2,200,000	2,200,000	0.45	
	Sand	Simplified Thermal	2	3	2,600,000	2,600,000	0.255	



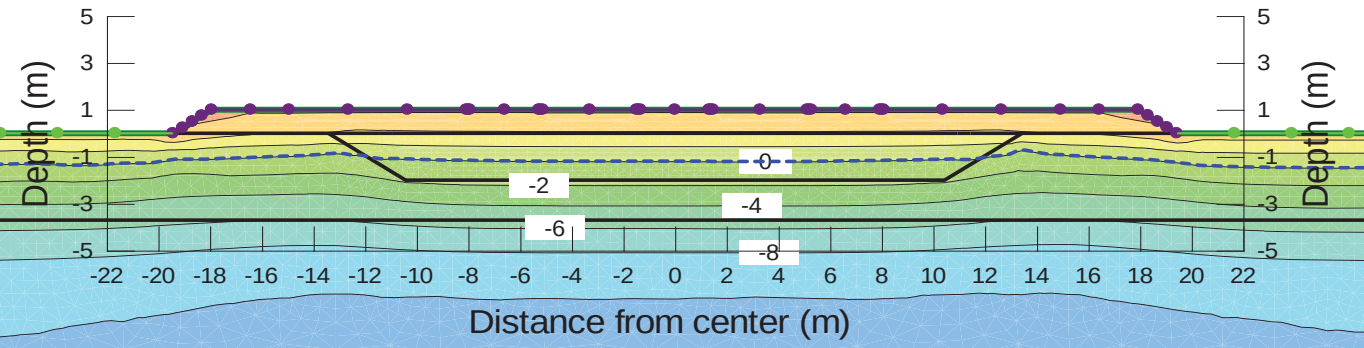
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Ref		Crusher Building		Thermal Model - No Insulation			Milne Inlet Port		
By		Lk	GQ				10-Apr-18	FIGURE C2-1	
Revision		A					10-Apr-18		

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Name: Base Crusher Plant - 2m Foundation
Date: 3/28/2018
Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\



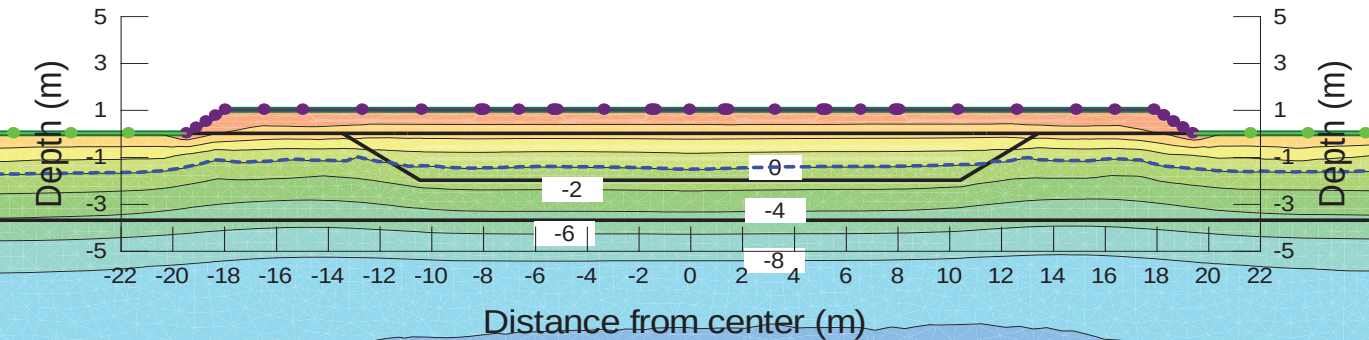
Job number		353004		Mary River Expansion Project			BIM		
Ref		Crusher Building		No Insulation Temperature Contour In Summer (2 yr after construction)			Milne Inlet Port		
By		Lk	GQ				10-Apr-18		
Revision		A					10-Apr-18		
								FIGURE C2-2	

File Name: Crusher Plant updated V2.gsz
Name: Base Crusher Plant - 2m Foundation
Date: 3/28/2018
Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\



Job number		353004		Mary River Expansion Project			BIM		
Ref		Crusher Building		No Insulation Temperature Contour In Summer (10 yr after construction)			Milne Inlet Port		
By		Lk	GQ				10-Apr-18		
Revision		A					10-Apr-18		
								FIGURE C2-3A	

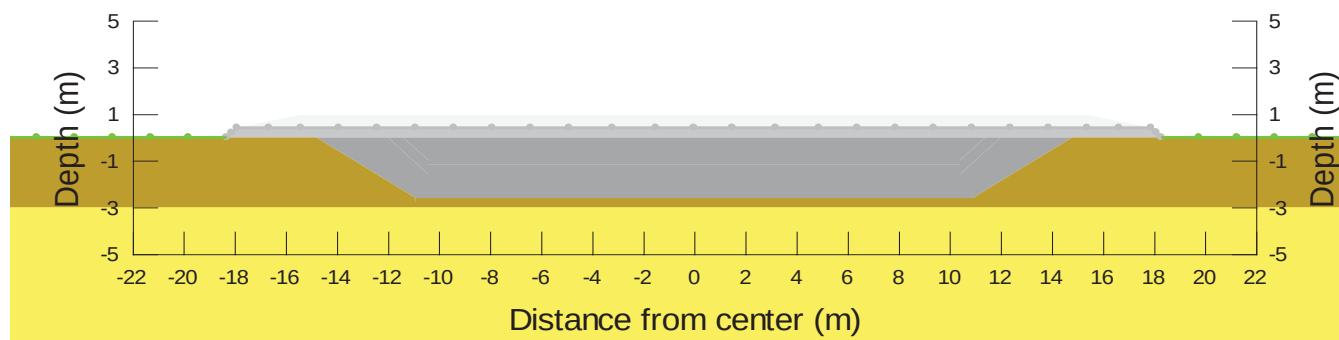
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Job number		353004		Mary River Expansion Project			BIM		
Ref		Crusher Building		No Insulation Temperature Contour In Summer (20 yr after construction)			Milne Inlet Port		
By		Lk	GQ				10-Apr-18		
Revision		A					10-Apr-18		
								FIGURE C2-3B	

File Name: Screening Plant_thermal_updated.gsz
Name: May start date (2.6m pad)
Date: 3/28/2018
Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\

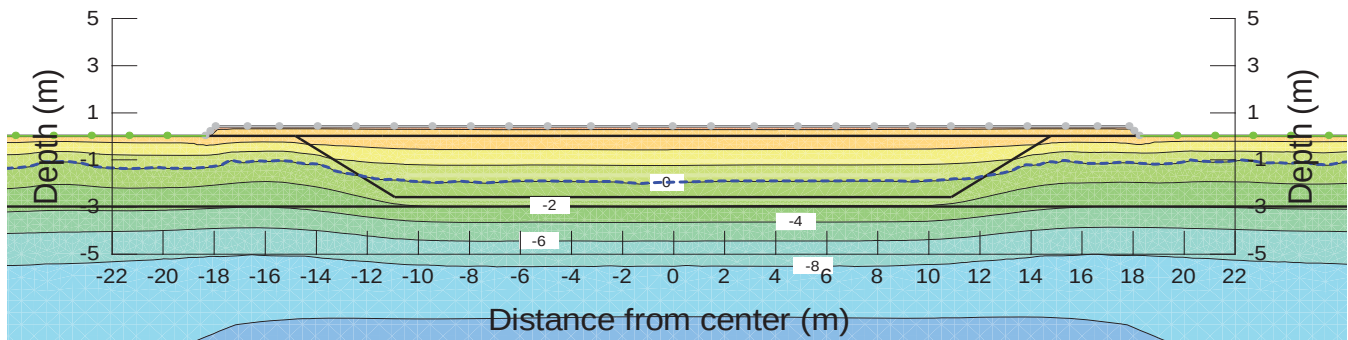
Color	Name	Model	Unfrozen Thermal Conductivity (J/sec/m/°C)	Frozen Thermal Conductivity (J/sec/m/°C)	Unfrozen Volumetric Heat Capacity (J/m³/°C)	Frozen Volumetric Heat Capacity (J/m³/°C)	Vol W/C (m³/m³)	Initial Temperature (°C)
	Rockfill above ground	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	0
	Rockfill Pad	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	-3
	Silt	Simplified Thermal	1.3	2	2,200,000	2,200,000	0.45	
	Sand and Gravel	Simplified Thermal	2	3	2,600,000	2,600,000	0.255	



Job number		353004		Mary River Expansion Project			BIM		
Ref	Screening Building			Thermal Model - No Insulation			Milne Inlet Port		
By	Lk	GQ	10-Apr-18						
Revision		A	10-Apr-18						
								FIGURE C2-4	

Fig C2-4 | 4/10/2018 3:35 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\Summary\Figure Thermal Model - Combined v4.xlsx

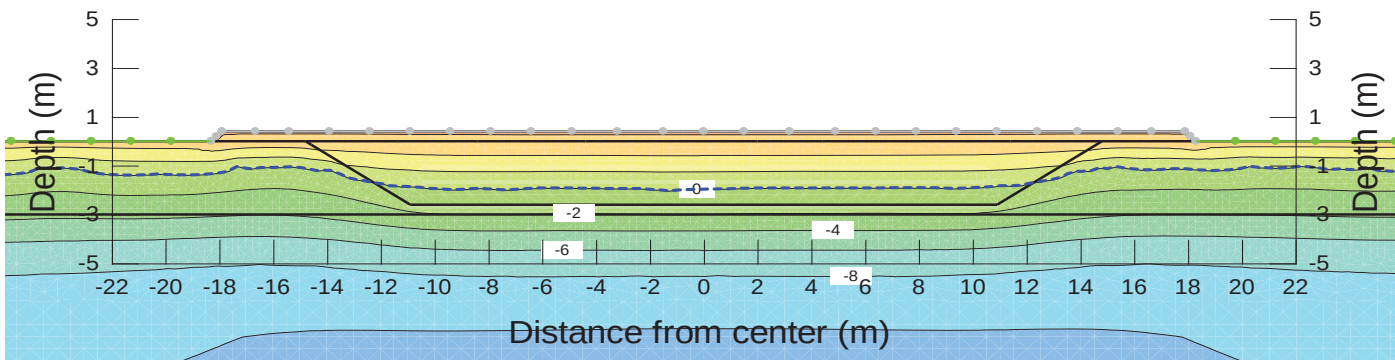
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 Date: 3/28/2018
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Job number		353004		Mary River Expansion Project			BIM		
Ref		Screening Building		No Insulation Temperature Contour In Summer (2 yr after construction)			Milne Inlet Port		
By		Lk	GQ				10-Apr-18		
Revision		A					10-Apr-18		
								FIGURE C2-5	

Fig C2-5 | 4/10/2018 3:35 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\Summary\Figure Thermal Model - Combined v4.xlsx

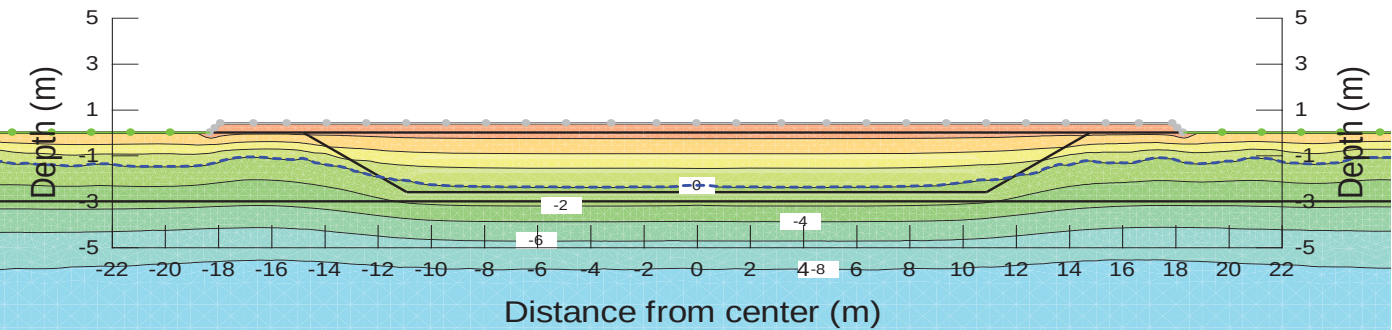
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Date: 3/28/2018
Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\



Job number		353004		Mary River Expansion Project			BIM			
Ref	Screening Building						No Insulation Temperature Contour In Summer (10 yr after construction)		Milne Inlet Port	
By	Lk	GQ	10-Apr-18						FIGURE C2-6A	
Revision		A	10-Apr-18							

Fig C2-6A | 4/10/2018 3:35 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\Summary\Figure Thermal Model - Combined v4.xlsx

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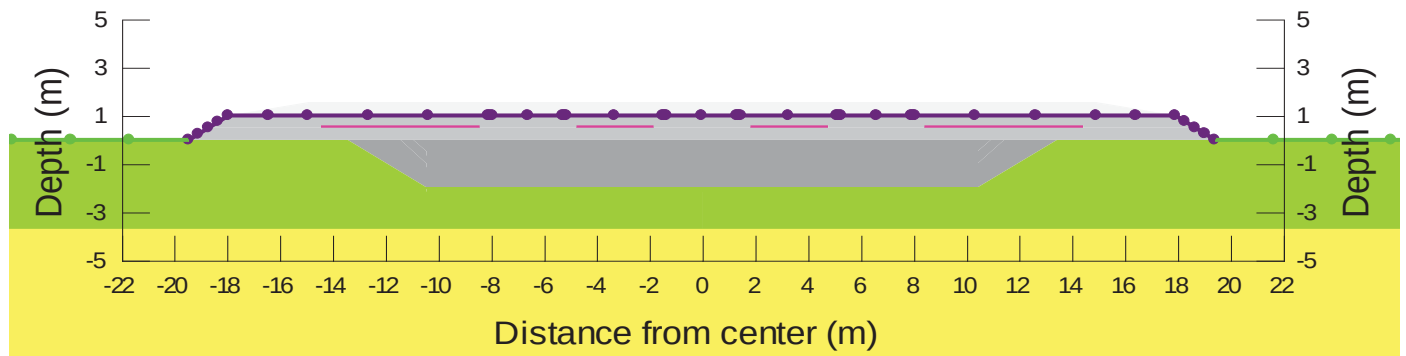


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By		Lk	GQ						10-Apr-18	
Revision		A							10-Apr-18	
								FIGURE C2-6B		

Fig C2-6B | 4/10/2018 3:35 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\Summary\Figure Thermal Model - Combined v4.xlsx

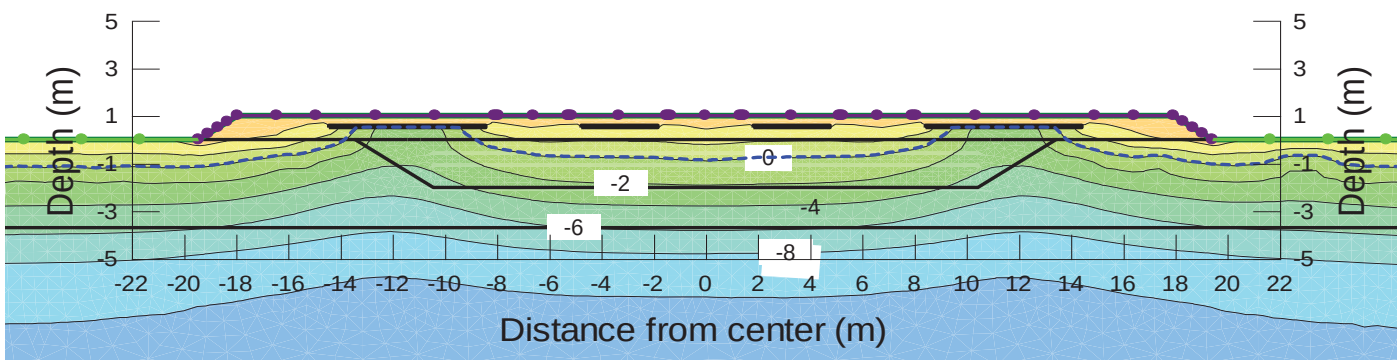
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 Date: 3/29/2018
 Directory : P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\

Color	Name	Model	Unfrozen Thermal Conductivity (J/sec/m ² °C)	Frozen Thermal Conductivity (J/sec/m ² °C)	Unfrozen Volumetric Heat Capacity (J/m ³ °C)	Frozen Volumetric Heat Capacity (J/m ³ °C)	Vol W/C (m ³ /m ³)	Initial Temperature (°C)
	Rockfill above ground	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	0
	Rockfill Pad	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	-3
	Silt	Simplified Thermal	1.3	2	2,200,000	2,200,000	0.45	
	Insulation	Simplified Thermal	0.035	0.035	37,500	37,500	0	0
	Sand	Simplified Thermal	2	3	2,600,000	2,600,000	0.255	



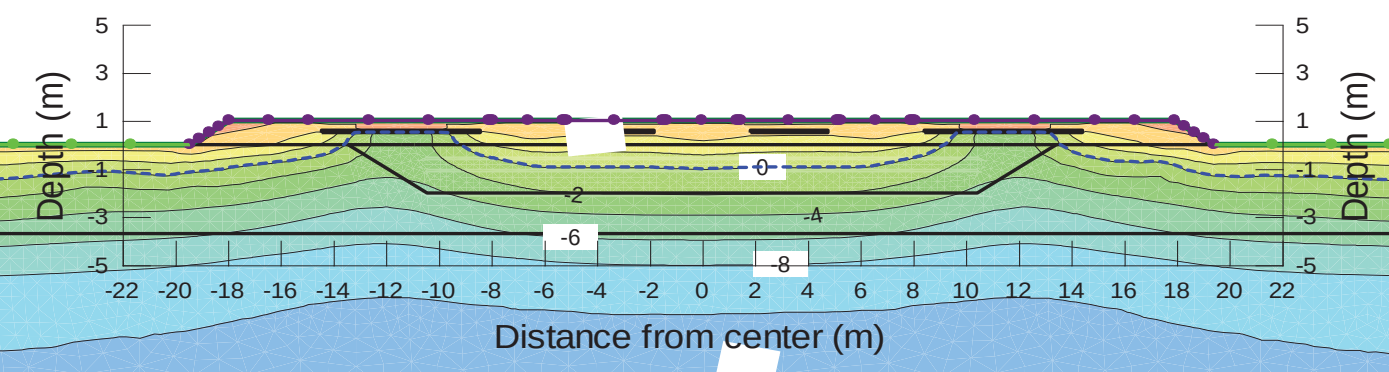
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Ref	Crusher Building						Thermal Model - Modified Insulation Geometry		Milne Inlet Port	
By	Lk	GQ	10-Apr-18						FIGURE C2-7A	
Revision		A	10-Apr-18							

File Name: Crusher Plant updated V2.gsz
Name: Base Crusher Plant - 2m Foundation - 150 mm Insulation in Found
Date: 3/29/2018
Directory : P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\



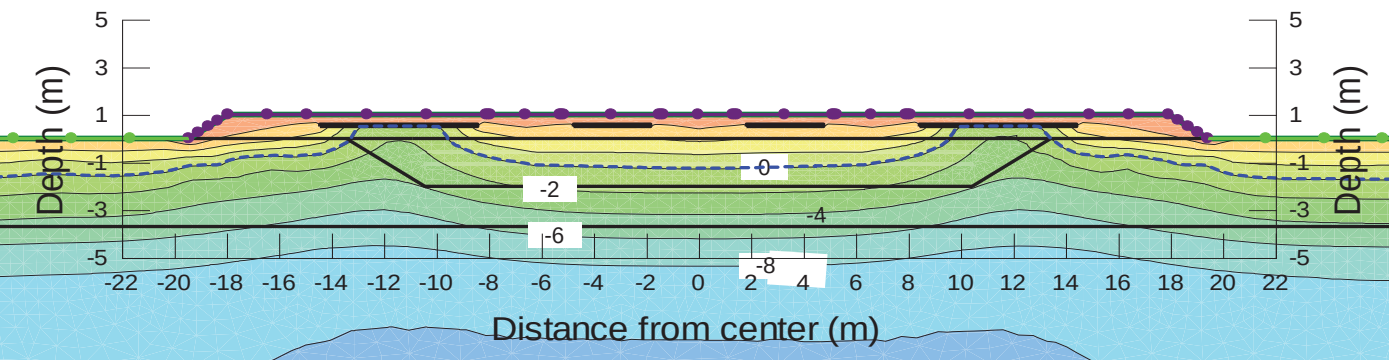
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Ref		Crusher Building					Milne Inlet Port	
By		Lk	GQ	10-Apr-18				
Revision		A		10-Apr-18				
				Modified Insulation Geometry Temperature Contour In Summer (2 yr after construction)		FIGURE C2-7B		

File Name: Crusher Plant updated V2.gsz
Name: Base Crusher Plant - 2m Foundation - 150 mm Insulation in Found
Date: 3/29/2018
Directory : P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\



Job number		353004		Mary River Expansion Project			BIM		
Ref		Crusher Building		Modified Insulation Geometry Temperature Contour In Summer (10 yr after construction)			Milne Inlet Port		
By		Lk	GQ				10-Apr-18		
Revision		A					10-Apr-18		
								FIGURE C2-7C	

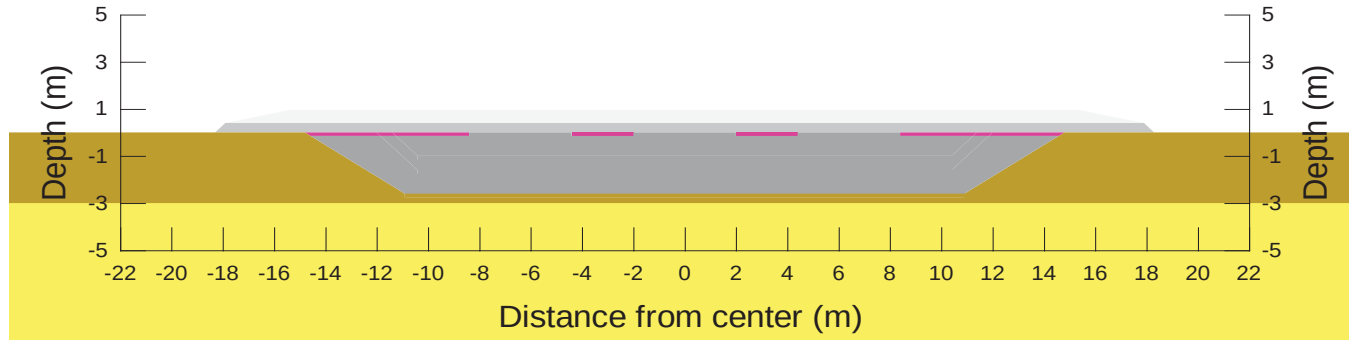
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Date: 3/29/2018
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Job number		353004		Mary River Expansion Project			BIM		
Ref	Crusher Building			Modified Insulation Geometry Temperature Contour In Summer (20 yr after construction)			Milne Inlet Port		
By	Lk	GQ	10-Apr-18						
Revision		A							10-Apr-18
								FIGURE C2-7D	

File Name: Screening Plant_thermal_updated.gsz
 Name: May (2.6 m Pad) + Insulation in Found
 Date: 3/28/2018
 Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\

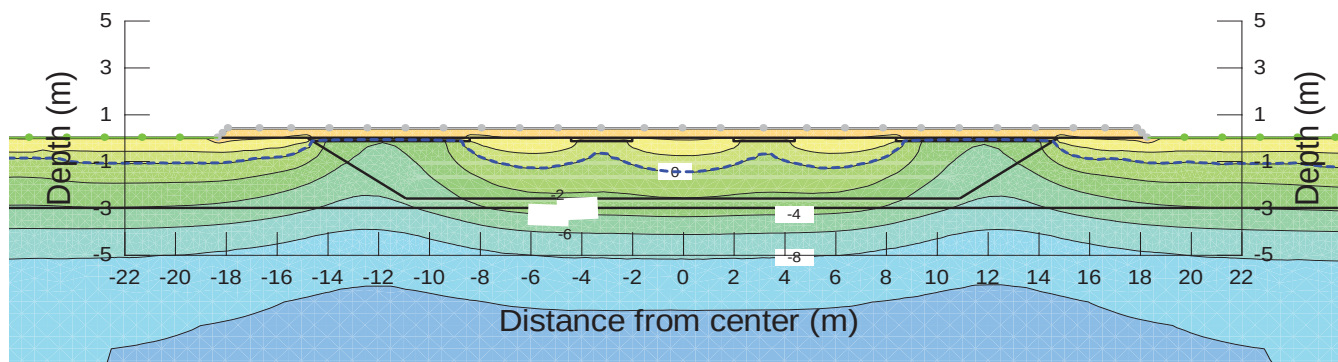
Color	Name	Model	Unfrozen Thermal Conductivity (J/sec/m ² °C)	Frozen Thermal Conductivity (J/sec/m ² °C)	Unfrozen Volumetric Heat Capacity (J/m ³ °C)	Frozen Volumetric Heat Capacity (J/m ³ °C)	Vol W/C (m ³ /m ³)	Initial Temperature (°C)
	Rockfill above ground	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	0
	Rockfill Pad	Simplified Thermal	3	4.5	3,000,000	2,400,000	0.036	-3
	Silt	Simplified Thermal	1.3	2	2,200,000	2,200,000	0.45	
	Insulation	Simplified Thermal	0.035	0.035	37,500	37,500	0	0
	Sand and Gravel	Simplified Thermal	2	3	2,600,000	2,600,000	0.255	



Job number		353004		Mary River Expansion Project			BIM		
Ref		Screening Building					Milne Inlet Port		
By	Lk	GQ	10-Apr-18				FIGURE C2-8A		
Revision		A	10-Apr-18						
				Thermal Model - Modified Insulation Geometry					

Fig C2-8A | 4/10/2018 3:35 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\Summary\Figure Thermal Model - Combined v4.xlsx

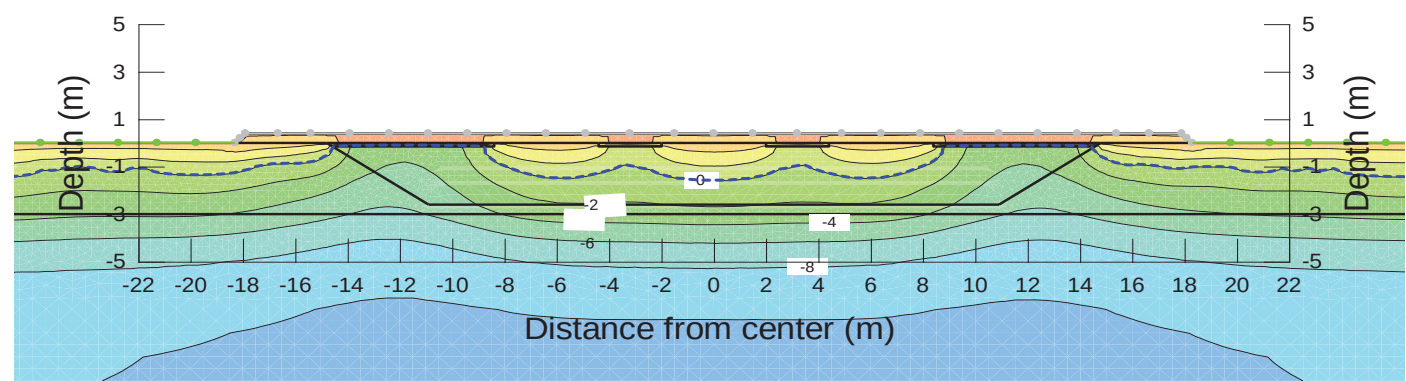
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 Date: 3/28/2018
 Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\



Job number		353004		Mary River Expansion Project			BIM		
Ref	Screening Building			Modified Insulation Geometry Temperature Contour In Summer (2 yr after construction)			Milne Inlet Port		
By	Lk	GQ	10-Apr-18						
Revision		A	10-Apr-18						
								FIGURE C2-8B	

Fig C2-8B | 4/10/2018 3:35 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\Summary\Figure Thermal Model - Combined v4.xlsx

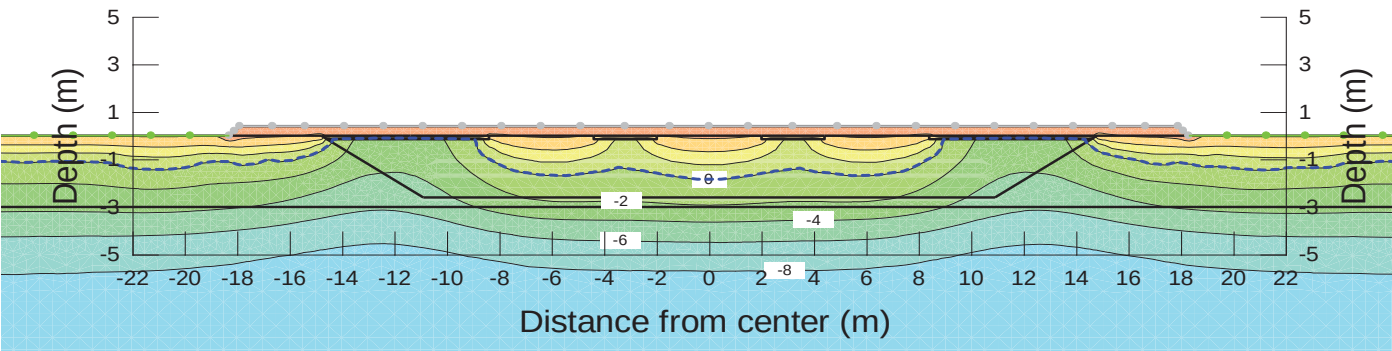
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Job number		353004		Mary River Expansion Project			BIM	
Ref	Screening Building						Modified Insulation Geometry Temperature Contour In Summer (10 yr after construction)	
By	Lk	GQ	10-Apr-18	FIGURE C2-8C				
Revision		A	10-Apr-18					

Fig C2-8C | 4/10/2018 3:35 PM | P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\Summary\Figure Thermal Model - Combined v4.xlsx

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Name: May (2.6 m Pad) + Insulation in Found
Date: 3/28/2018
Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Thermal models\



Job number		353004		Mary River Expansion Project			BIM		
Ref		Screening Building		Modified Insulation Geometry Temperature Contour In Summer (20 yr after construction)			Milne Inlet Port		
By		Lk	GQ				10-Apr-18		
Revision		A					10-Apr-18		
								FIGURE C2-8D	

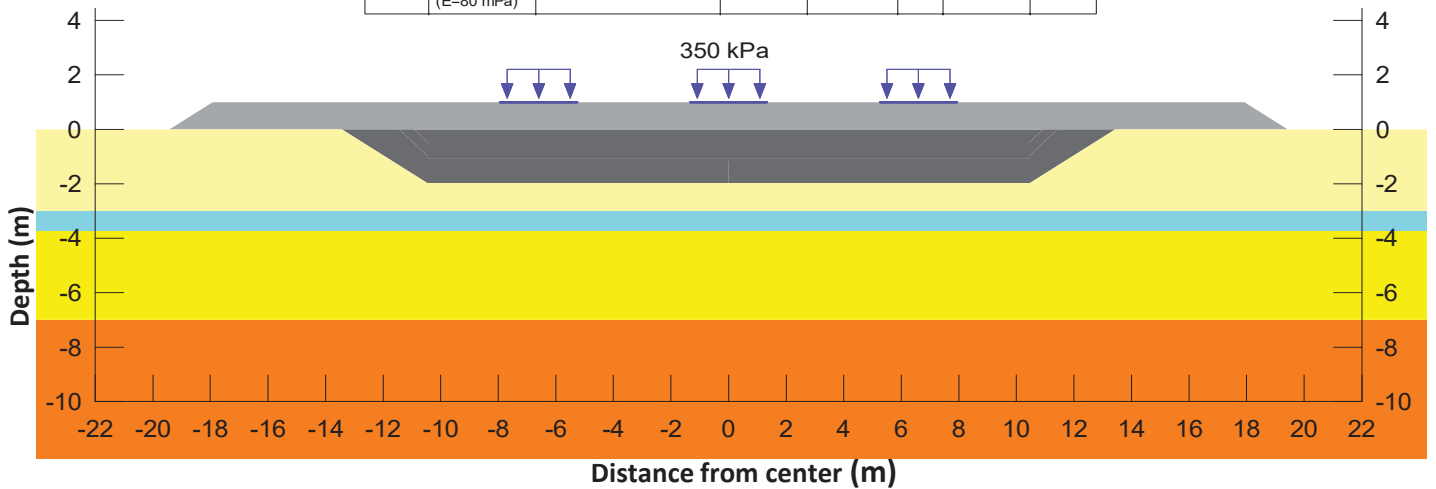
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Appendix C3

Settlement Analyses – Crushing/Screening Plant

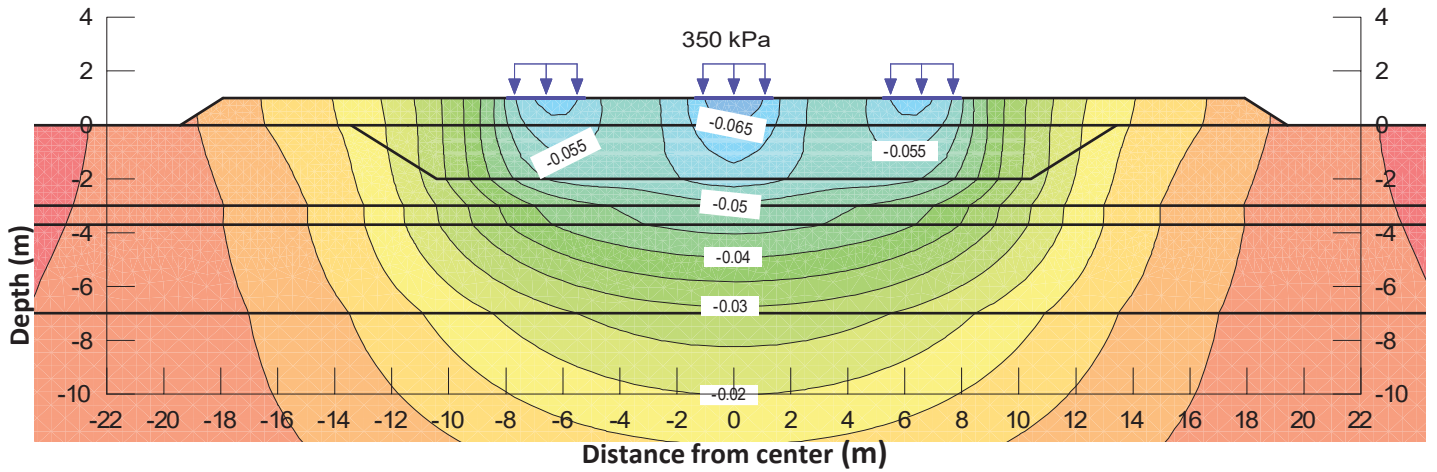
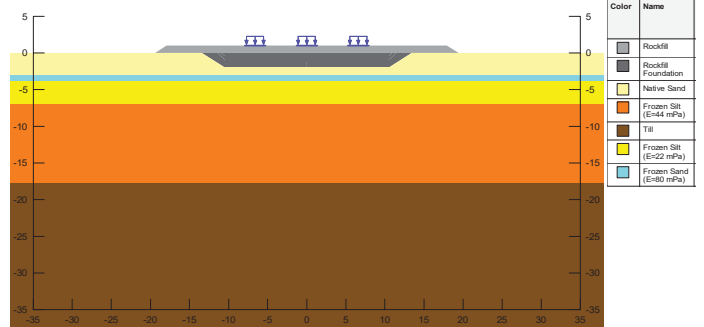
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 Date: 2/22/2018
 Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\

Color	Name	Model	Effective Young's Modulus (E') (kPa)	Cohesion' (kPa)	Phi' (°)	Poisson's Ratio	Unit Weight (kN/m³)
	Rockfill	Elastic-Plastic (Effective)	70,000	0	40	0.33	22
	Rockfill Foundation	Elastic-Plastic (Effective)	70,000	0	40	0.33	22
	Native Sand	Elastic-Plastic (Effective)	15,000	0	32	0.33	18
	Frozen Silt (E=44 mPa)	Elastic-Plastic (Effective)	44,000	0	30	0.33	18
	Till	Elastic-Plastic (Effective)	1,000,000	0	35	0.33	22
	Frozen Silt (E=22 mPa)	Elastic-Plastic (Effective)	22,000	0	30	0.33	18
	Frozen Sand (E=80 mPa)	Elastic-Plastic (Effective)	80,000	0	32	0.33	18



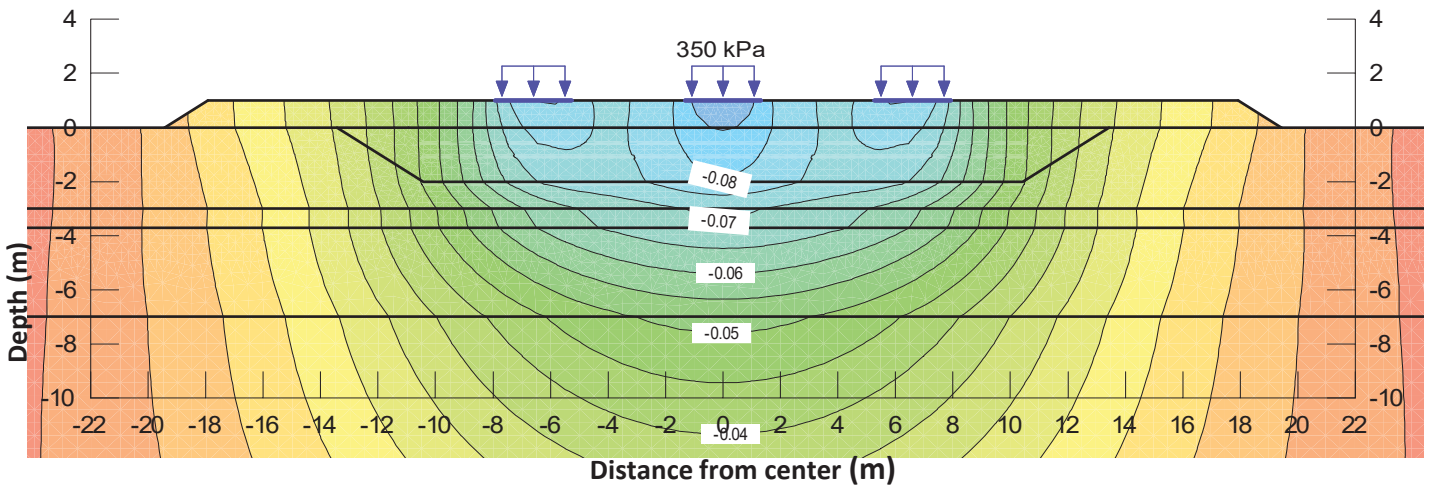
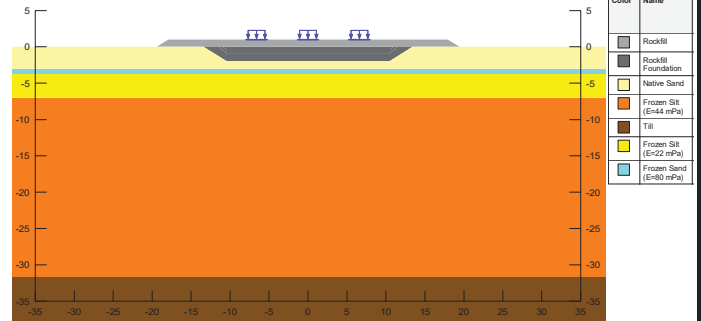
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Ref		Crusher Building		Settlement Model			Milne Inlet Port	
By	Lk	0	04-Mar-18				FIGURE C3-1	
Revision		A	04-Mar-18					

File Name: Crusher Plant Various Foundations.gsz
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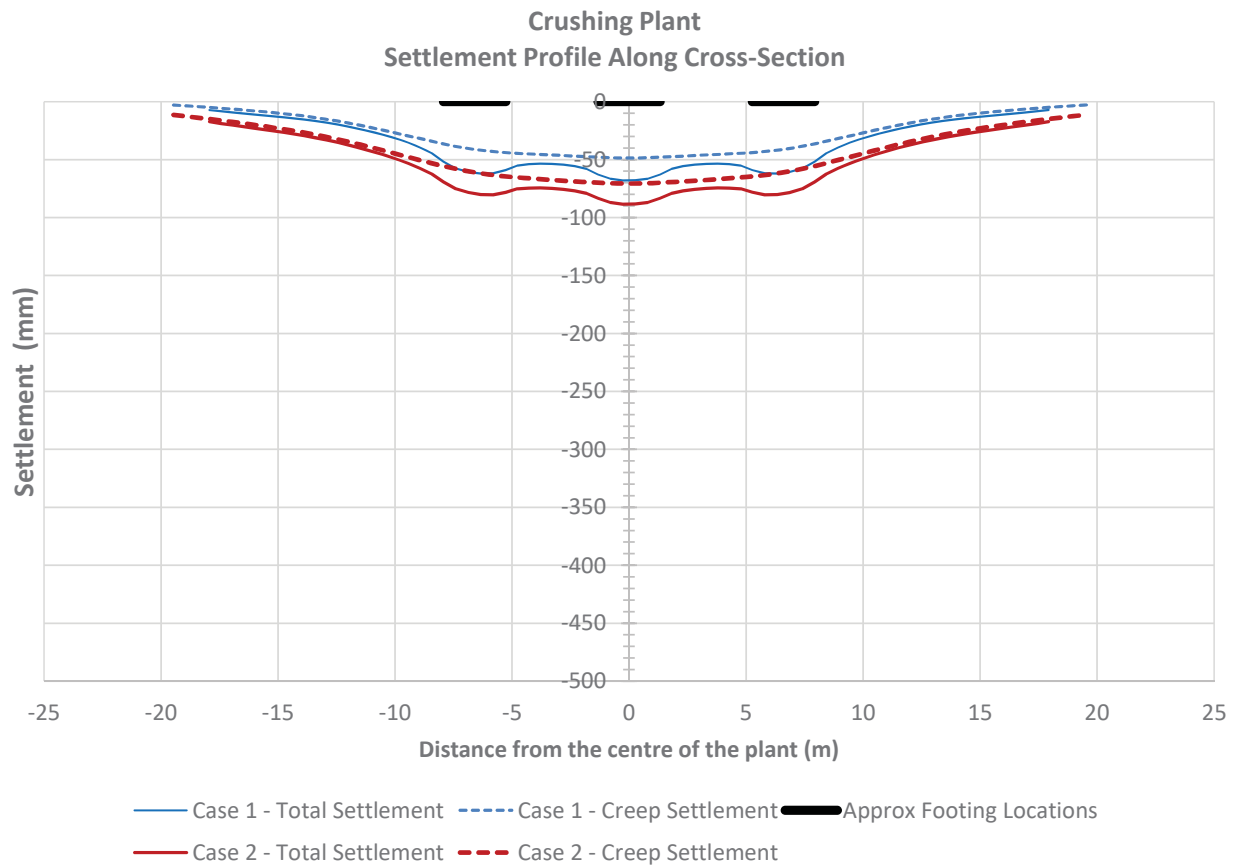


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Ref		Crusher Building		Case 1 Results			Milne Inlet Port	
By	Lk	0	04-Mar-18				FIGURE C3-2	
Revision		A	04-Mar-18					

File Name: Crusher Plant Various Foundations.gsz
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 Date: 2/22/2018
 Directory: P:\REDLEAF\335458\SPECIALIST_APPS\02 Marry River\03 Crusher Buildings\Settlement\Geo Models\



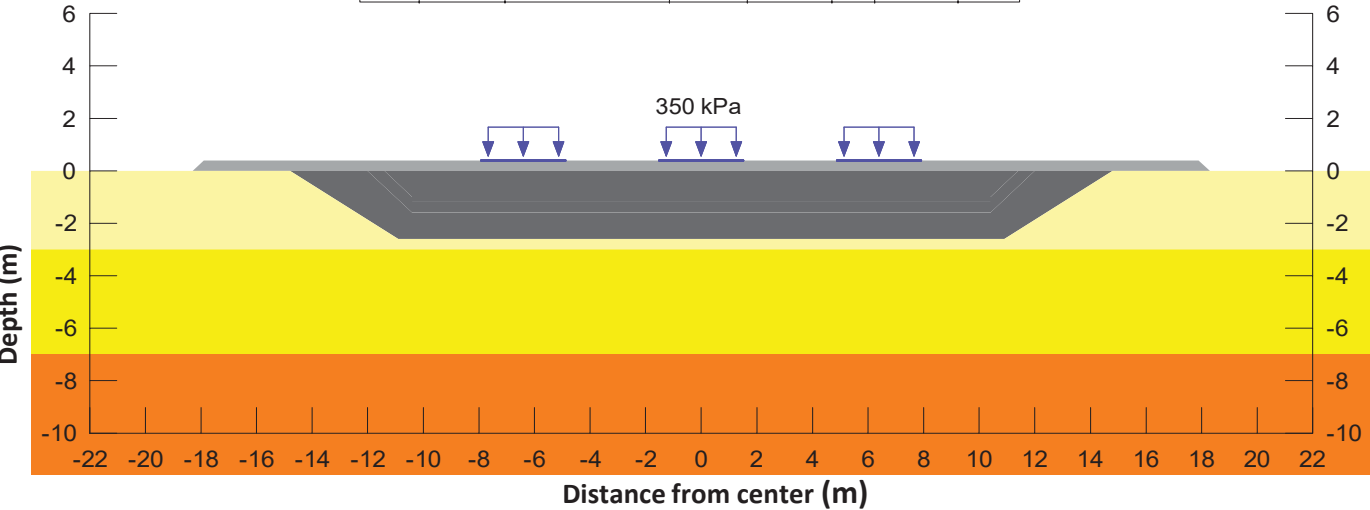
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By	Lk	0	04-Mar-18				FIGURE C3-3	
Revision		A	04-Mar-18					



Job number		353004		Mary River Expansion Project			BIM	
Ref	Crusher Building			Settlement Profile Summary			Milne Inlet Port	
By	Lk	0	04-Mar-18				FIGURE C3-4	
Revision		A	04-Mar-18					

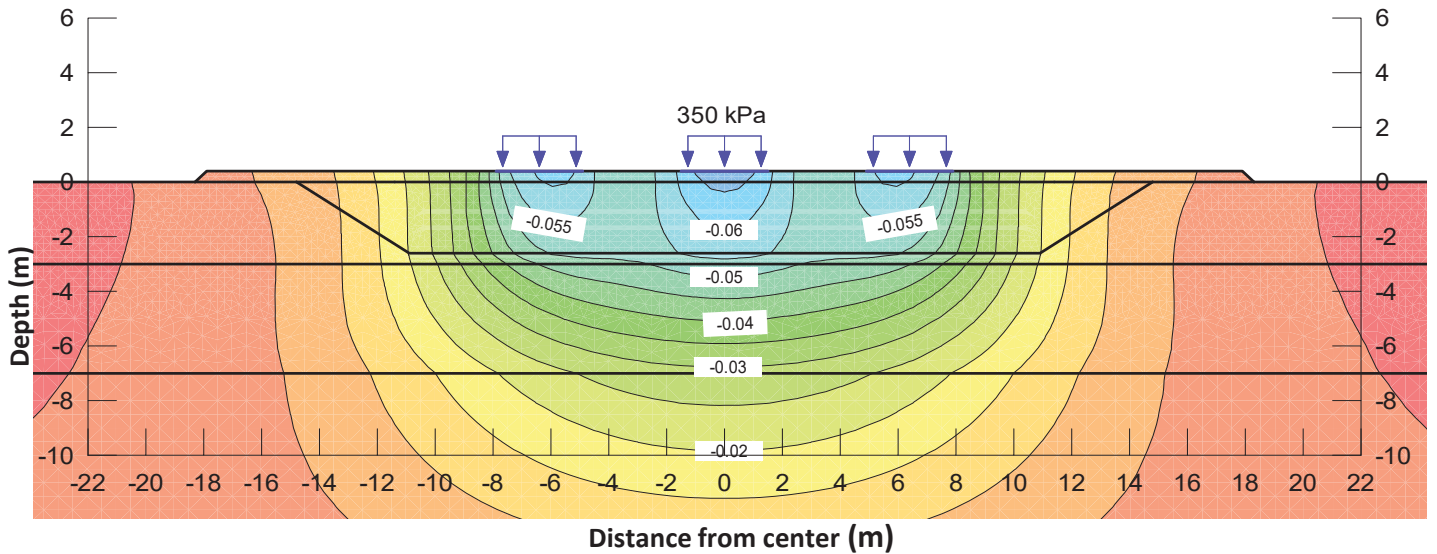
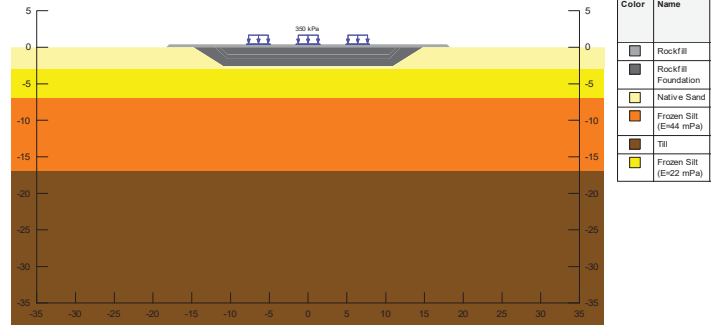
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Date: 2/23/2018
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Color	Name	Model	Effective Young's Modulus (E) (kPa)	Cohesion' (kPa)	Phi' (°)	Poisson's Ratio	Unit Weight (kN/m³)
	Rockfill	Elastic-Plastic (Effective)	70,000	0	40	0.33	22
	Rockfill Foundation	Elastic-Plastic (Effective)	70,000	0	40	0.33	22
	Native Sand	Elastic-Plastic (Effective)	15,000	0	32	0.33	18
	Frozen Silt (E=44 mPa)	Elastic-Plastic (Effective)	44,000	0	30	0.33	18
	Till	Elastic-Plastic (Effective)	1,000,000	0	35	0.33	22
	Frozen Silt (E=22 mPa)	Elastic-Plastic (Effective)	22,000	0	30	0.33	18



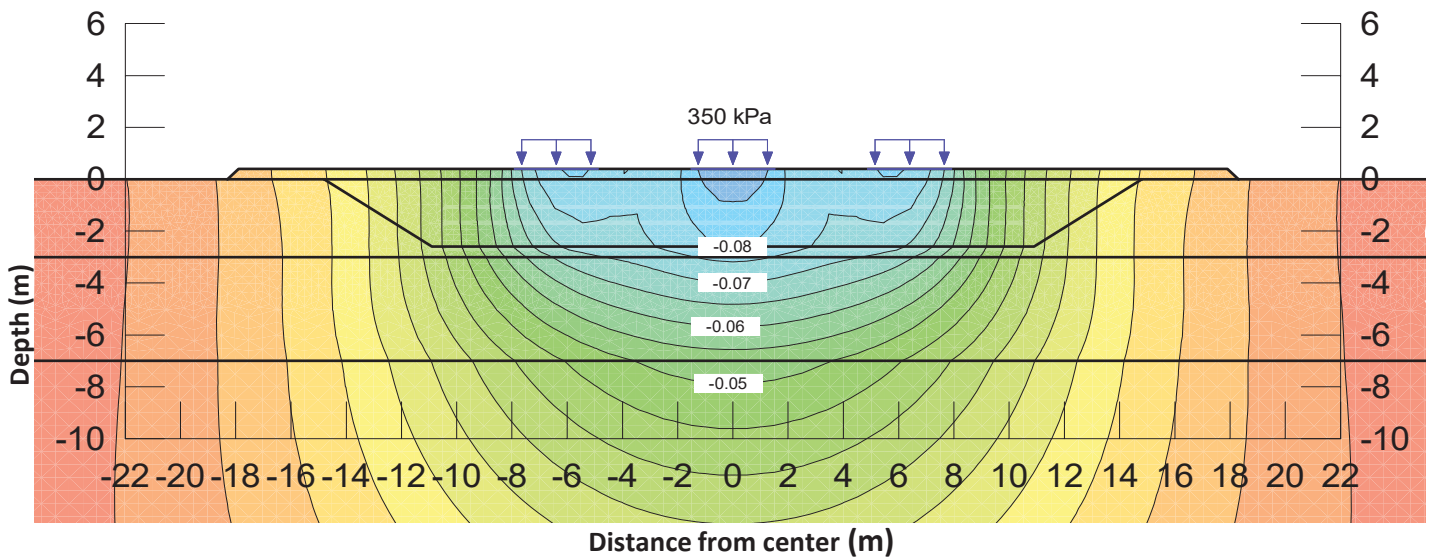
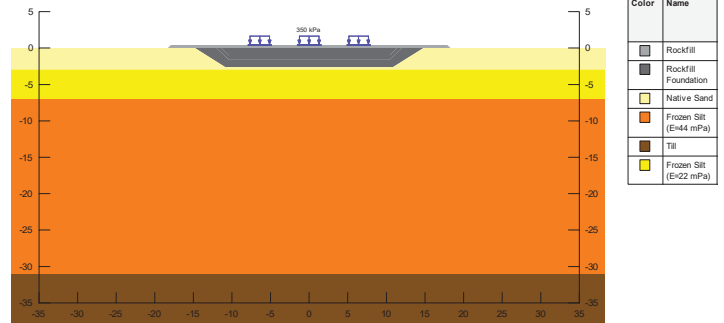
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Ref		Screening Buildings		Settlement Model			Milne Inlet Port		
By		Lk	0				04-Mar-18		
Revision		A	04-Mar-18						
								FIGURE C3-5	

File Name: Screening Plant.gsz
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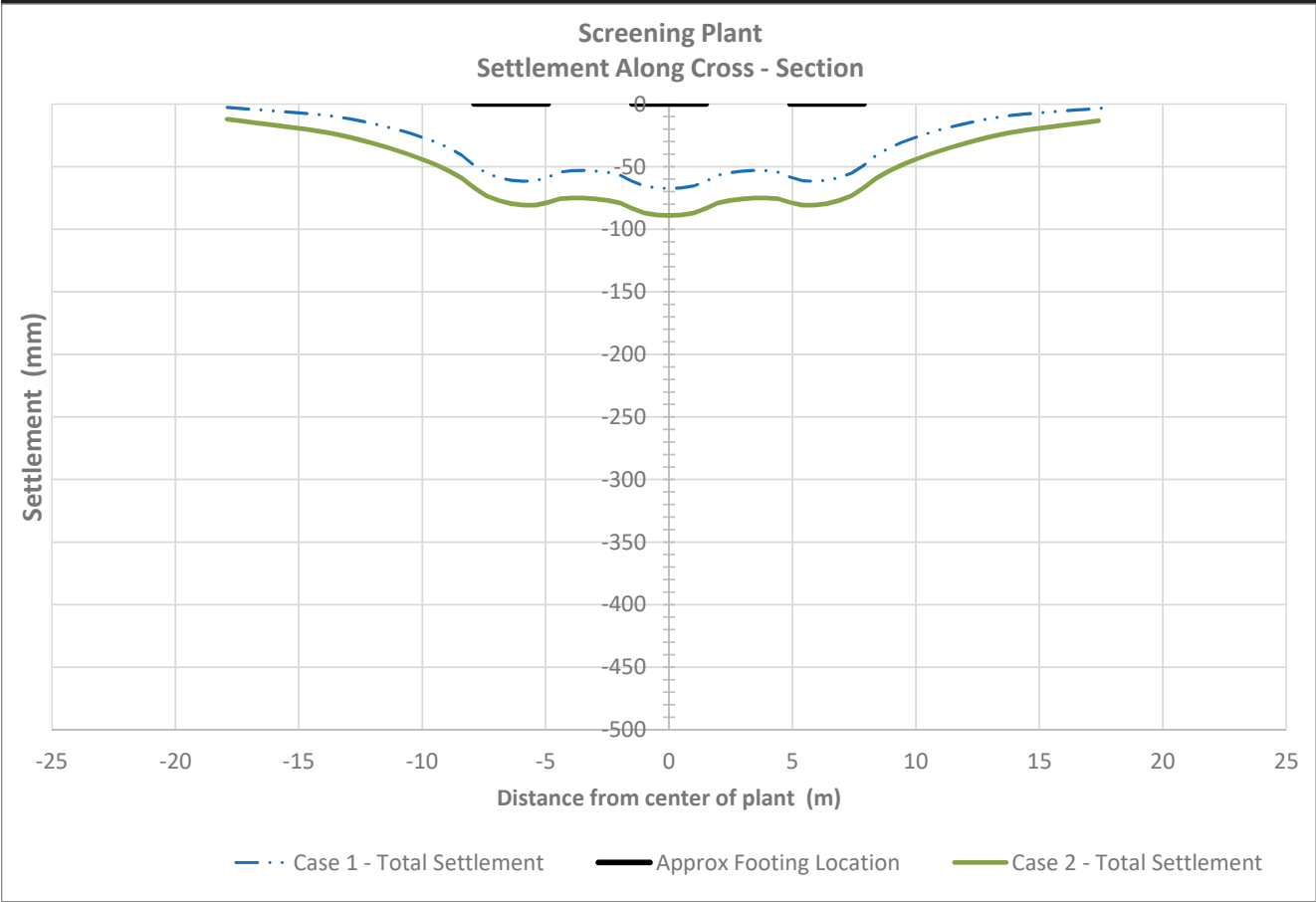


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By	Lk	0	04-Mar-18				FIGURE C3-6	
Revision		A	04-Mar-18					

File Name: Screening Plant.gsz
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 Date: 2/23/2018
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Job number		353004		Mary River Expansion Project			BIM		
Ref		Screening Buildings		Case 2 Results			Milne Inlet Port		
By		Lk	0				04-Mar-18		
Revision		A	04-Mar-18						
								FIGURE C3-7	



Job number		353004		Mary River Expansion Project Settlement Profile Summary		HATCH		BIM	
Ref		Screening Buildings						Milne Inlet Port	
By		Lk	0					04-Mar-18	
Revision		A						04-Mar-18	
								FIGURE C3-8	